THE POTENTIAL OF MICROFOSSIL USE IN PALEODIET AND PALEOENVIONMENTAL ANALYSIS IN NORTHWESTERN ONTARIO

By

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ABSTRACT

Historically wild rice was important economically and spiritually across much of central and eastern Canada, but the antiquity of its use by Native communities is unclear. Unlike plant macrofossils, which have traditionally been used to identify this plant in prehistoric contexts, silicophytoliths preserve well in archaeological sites and in carbonized food residue encrusted on clay pots. This proxy, therefore, promises to yield considerable new insight into the antiquity and intensity of wild rice harvesting in this region.

Various phytolith types from various grasses, sedges and aquatic plants were examined. However, the focus was kept on rondel phytoliths, a form only produced in grasses. Thirty-eight grass species were examined, including two species of wild rice (*Zizania aquatica* and *Zizania palustris*). A minimum of three hundred rondels from each grass species were counted from various parts of the plant including the inflorescence, the leaf and the stem. Based on extensive morphological comparisons of phytoliths produced by wild rice (*Zizania* spp.), and other native Boreal and Prairie grasses and maize (*Zea mays*), several phytolith morphotypes were identified that are produced only in wild rice (*Zizania* spp.). In general, rondels with four spikes, with one and three indentations, are characteristic of *Zizania* (spp.). However, differences between the two wild rice species were not established.

Lake sediments from Lulu Lake in the Lake of the Woods area where modern wild rice grows were analysed to determine if the types identified as being diagnostic of wild rice would be present. As a preliminary analysis, the presence of wild rice (*Zizania* spp.) can be identified in small quantities in lake sediments. Therefore, wild rice (*Zizania* spp.) phytoliths can be a powerful tool in the identification of the plant in Holocene sediments.

Potsherds with encrusted carbonized residues from the Lake of the Woods and surrounding area were also examined for the presence of diagnostic wild rice (*Zizania* spp.) and maize (*Zea mays*) phytoliths. These archaeological samples are attributed to the Laurel (Middle

Woodland), Selkirk (Late Woodland), Blackduck (Late Woodland), and Sandy Lake (Late Woodland) cultures. Based on the use of diagnostic phytolith types for both wild rice (*Zizania* spp.) and maize (*Zea mays*), the presence of both these cultigens was identified in the residues of all four cultures mentioned above.

This is the first time maize (*Zea mays*) and wild rice (*Zizania* spp.) have been positively identified in prehistoric carbonized food residues from the Boreal Forest. Based on pottery types, wild rice (*Zizania* spp.) and maize (*Zea mays*) were consumed as early as the Middle Woodland period (Laurel phase). Based on the samples examined, the evidence of maize (*Zea mays*) phytoliths in the residue is greater than those of wild rice (*Zizania* spp.). However, this might reflect sample bias or most likely biases due to processing of the plants before consumption. Therefore, the absence of a wild rice (*Zizania* spp.) phytolith signature might not represent that the plant was not consumed, rather that the parts of the plant with the diagnostic phytolith types were removed before consumption.

Maize (*Zea mays*) horticulture during the Late Woodland period in the Lake of the Woods and surrounding area does not seem likely because there is no evidence of gardening, or heavy consumption of this plant. However, the latter might not be necessary for local horticulture. In contrast, wild rice (*Zizania* spp.) stands are common in the Lake of the Woods and surrounding area, and therefore local harvesting of this plant is inferred.

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DEDICATION

The writing of this thesis has been particularly difficult for me, on June 23, 2007, my younger brother Mathieu Surette died in an unfortunate car accident in my hometown of Grande-Digue, New Brunswick. I had not seen my brother very often in four years, he had been working in Red Deer Alberta on the oil rigs, I was very grateful that I was able to see him one last time two weeks before his death when he stopped to visit me here in Thunder Bay. My brother never quite understood the kind of work I did during the many years I spent at Lakehead University until I took him for a visit at the university and showed him what I did. He still did not grasp everything that I was doing but at least he had a clearer picture and all this was very impressive for him. I am happy I was able to share the work in this thesis with him. He will be missed, but will always be in our hearts and our memories. My brother always looked up to me, believed in me and what I would accomplish, this is why I am dedicating my thesis to his memory.

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CHAPTER 1: INTRODUCTION

1.1. INTRODUCTION

The Northernmost extent of wild rice is not well established. Previous pollen studies suggest that wild rice spread across the Upper Great Lakes and beyond beginning sometime in the late Holocene (McAndrews, 1969) and that that the first appearance and spread of wild rice (*Zizania palustris*) may be linked to the movement of the Laurel culture (Buchner, 1979; Stoltman, 1973). However, very few pollen studies have actually been undertaken to address this question, and so our understanding of the timing of the spread of this plant is generally poor, especially in northwestern Ontario, and there is limited understanding of the cause-and-effect relationship between Laurel and wild rice (*Zizania palustris*) (did people spread it? Did it spread due to climate, and people were merely exploiting it in its natural range?).

Paleodiets, especially the plant component of the different cultures (Laurel, Blackduck, Selkirk, and Sandy Lake) in the Lake of the Woods and surrounding area (Figure 1) are poorly understood. It is not clear why so many archaeological sites are concentrated in close proximity to modern wild rice stands (Rajnovich, 1984). Also, some cultures (Blackduck, Sandy Lake) found in the Lake of the Woods area, have demonstrated use of maize in other areas of their range. However, due to the lack of local ethnobotanical research in the area, the identification of potentially important plants consumed by prehistoric people has been difficult. Due to highly acidic soils, even the faunal component of most archaeological sites in the area does not tend to survive (Wright, 1995), and excavation techniques (floatation) in the past have not always focused on the recovery of floral materials.

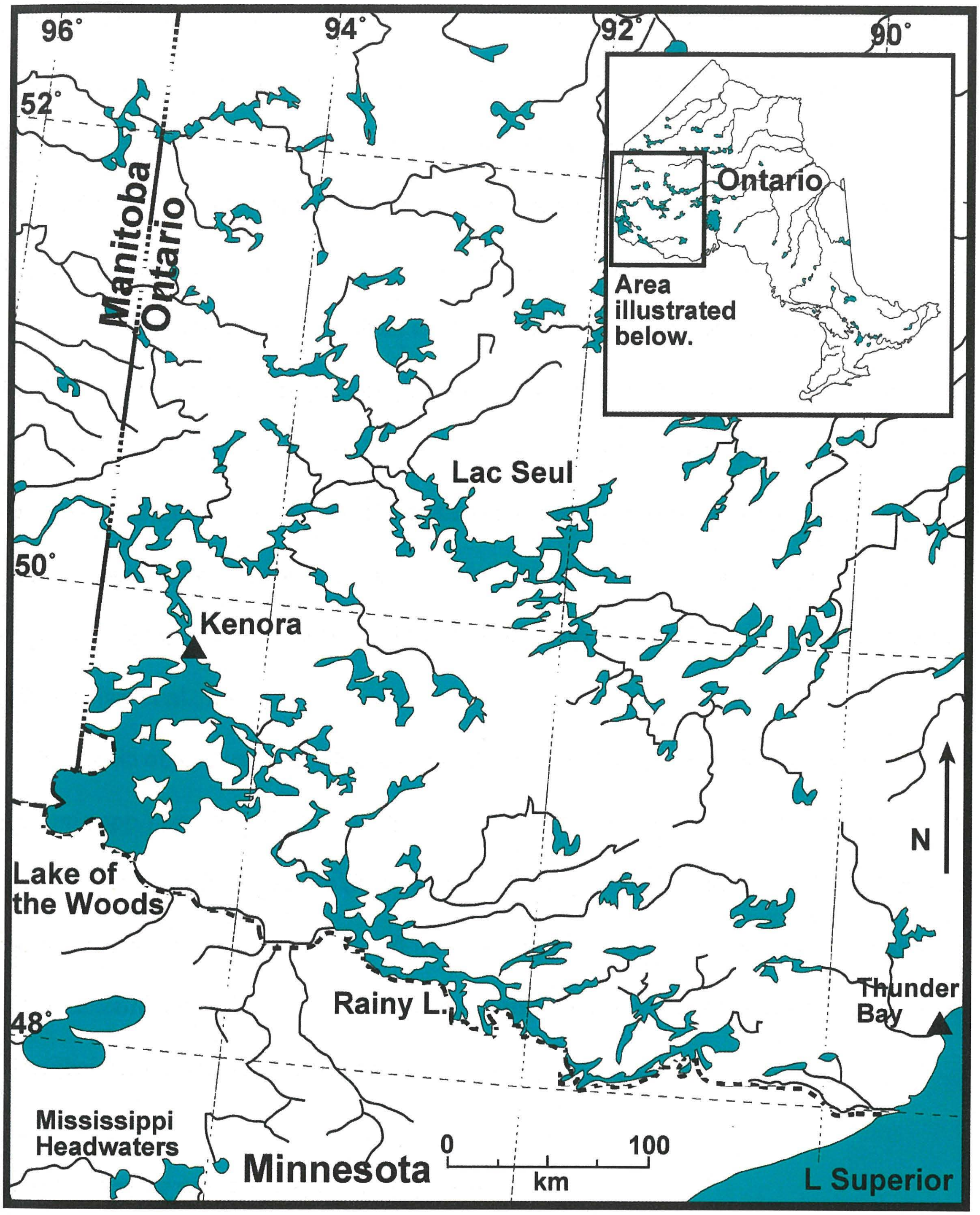

Figure 1. Lake of the Woods and surrounding area (from Hamilton, 2007)

Due to the lack of macrofossil remains, pollen, phytoliths, and starch have been employed to infer the use of plants during prehistoric times. The identification of wild rice through pollen grain analysis of lake sediments has been established on the basis of its size for a number of years (McAndrews, 1969); however recent work by Lee et al. (2004) demonstrated that there are some problems with this assumption. Size ratios, and to some degree, the morphology of rondel phytoliths have also been employed by some (Hart et al., 2003) to determine the presence of wild rice (*Zizania* spp.) in carbonized food residues. However, only a few other key economic grasses were examined for comparison. Contamination, local climate and growing conditions, and environment are also other issues that may have potential impacts on the production and size of phytoliths (Brown, 1984; Piperno, 2006). Ball and Brotherson (1992) demonstrated that the morphology of grass phytoltihs does not change very much due to genetic control compared to size, which can be influenced by environment changes. Taxonomic systems for grass phytoliths are still in their infancy, of course a few taxonomic systems exist, but only a few focus on the rondel phytolith types produced in the inflorescence, and are limited at best (see Hart et al., 2003).

The main objectives of this thesis are to determine if wild economic grasses such as wild rice (*Zizania* spp.) produce diagnostic types of phytoliths and if they can easily be distinguished from other grasses, including maize (*Zea mays*); if the diagnostic types identified could be used to identify wild rice in lake sediments; and if the diagnostic types of phytoliths identified can be applied to determine whether or not people were consuming wild or cultivated plants in the past, based on their identification in food residues.

1.2. AN OVERVIEW OF THE STUDY AREA

The major vegetation zones in the study area consist of the Boreal and Great Lakes-St. Lawrence forests (Meyer and Hamilton, 1994) (Figure 2). The Boreal forest is characterized by the predominance of coniferous trees, which is dominated by four genera: spruce (*Picea*), fir (*Abies*), larch (*Larix*), and pine (*Pinus*). However, deciduous trees such as birch (*Betula*) and Poplar (*Populus*) are also present (Larsen, 1980). Its distribution is closely related to climate, which is characterised by long, extremely cold, dry winters and short, cool, moist summers (Larsen, 1980). Meyer and Hamilton (1994) describe Boreal forest ecology as being a complex patchwork of localized communities with highly variable levels of usable biomass. Therefore, the diversity of plants and animals in this area, as well as the ease of travel on the great numbers of lakes and rivers in the area, might have been very attractive to prehistoric populations. It has been suggested that during the Late Prehistoric period, the presence of wild rice (*Zizania* sp.) would have been of great importance to the subsistence economies of people living in the area (Meyer and Hamilton, 1994). The Great Lakes-St. Lawrence forest region is a mix of coniferous and deciduous trees, distinguished by the presence of eastern white and red pines, eastern hemlock, and yellow birch. Furthermore, the climate in the Great Lakes-St. Lawrence forest region has up to 120 frost-free days (Meyer and Hamilton, 1994), which might have allowed the growth of maize by prehistoric people in the area, assuming good soils could be found.

Lake of the Woods is a large inland lake in western Ontario within a transitional zone between northern boreal forest and prairie environments measuring approximately 90 by 120 km with more than 14, 000 islands (Wall, 1980a). The area is comprised of two ecological zones: the Boreal Forest Region and the Great-Lakes-St. Lawrence Forest region (Figure 2). The Lake of the Woods area lies in the warmer microthermal area of Canada, this area's climate is classed as moist sub-humid (characterized by cold winters and fairly warm summers) compared to the sub-humid cool continental climate that exists elsewhere in Northwestern Ontario (Hills, 1969; Sanderson, 1948). Due to the influence of the lake on air humidity, the Lake of the Woods region averages 128 frost-free days per year (Zoltai, 1965). Mean annual precipitation is approximately 66 cm per year (Reid, 1976).

South of Lake of the Woods, the Rainy River can be followed east towards Rainy Lake, which runs along the Canada-United States border. This area is often referred to as the "boundary waters" area. North of Lake of the Woods is the Kenora District. The Kenora

District is located within the Lake Winnipeg watershed division, which is in turn divided into two secondary watersheds: the English River watershed to the northeast and the Winnipeg River watershed to the southwest. The English River system flows west and empties in the Winnipeg River system (Spiedel, 1989). It lies partially within the Boreal Forest region and the transition zone between the Boreal and Great-Lakes-St. Lawrence Forest region, which is characterized by two climatic regions (on the basis of temperature and precipitation): the English River region to the north and the Rainy River region to the south, where the climate of both these regions can be classified as modified continental characterized by short, warm summers and long, cold winters (Spiedel, 1989). Lac Seul, the second largest body of water entirely within the province of Ontario, is located northeast of the Lake of the Woods runs also on the English River system.

Lake of the Woods and the surrounding area lies near the western edge of the Superior Province of the Canadian Shield (Douglas, 1976), with most of the area falling within the Cat Lake Belt, Quetico and Wabigoon subprovinces (Arthurs, 1986b). The area is rich in deposits of raw lithic materials, which would have been of interest to prehistoric hunter-gatherers. Glacial deposits not only provided good raw lithic materials, but also clays that would have been essential to the prehistoric potter (Arthurs, 1986b). The reader is referred to Arthurs (1986b) for a more detailed observation of the geology and deposits of the area.

Common faunal species (through observation, reported in the field or in the archaeological record) that have frequented the Lake of the Woods and surrounding area at one time or another include: white-tail deer (*Odocoileus virginianus*), moose (*Alces alces*), caribou (*Rangiefer caribou*), black bear (*Ursus americanus*), snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), duck (*Anatidae* sp.), loon (*Gavia immer*), ruffed grouse (*Bonasa umbellus*), northern pike (*Esox lucius*), lake trout (*Salvelinus namaycush*), sturgeon (*Acipenser fulvescens*), pickerel (*Stizostedion vitreum*), and whitefish (*Coregonus clupeiformis*) (Reid, 1976).

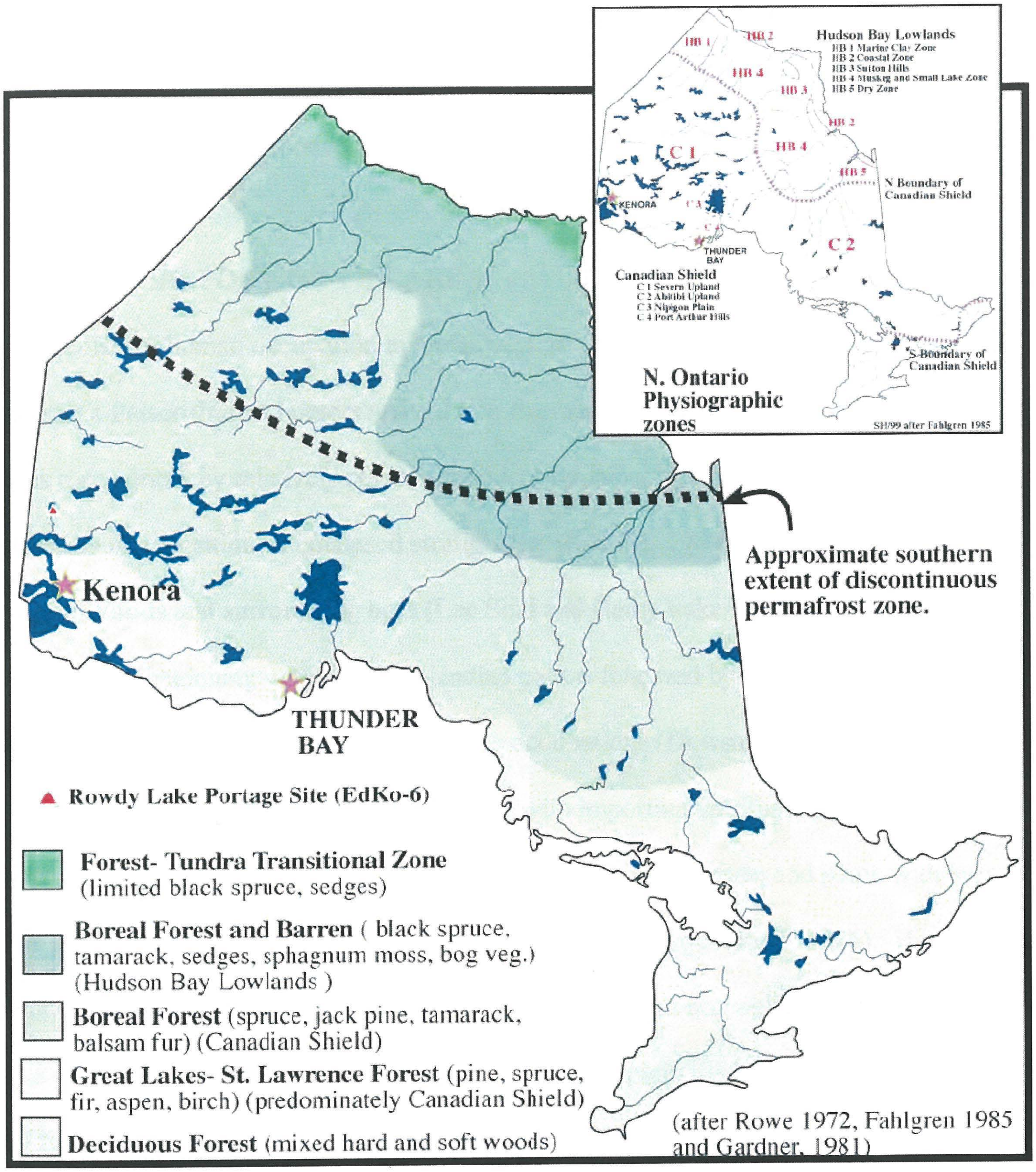

Figure 2. Forest communities in northwestern Ontario (from Hamilton, 2007).

A wide variety of plants exist in the Lake of the Woods and surrounding area that were exploited during the historic period by local natives, and most likely during the prehistoric period as well. Major species of plants such as wild rice (*Zizania palustris*), and other wild grasses such as Indian rice grass (*Oryzopsis* sp.) and the common reed (*Phragmites* sp.), arrowhead (*Sagittaria latifolia*), yellow pond lily (*Nuphar variegatum*), cattail (*Typha latifolia*) are among many economically useful plants growing in or around the wetlands, lakes and rivers in the area. Of course a large variety of berries, nuts, or other vegetables or seeds are also available, but they are not as economically productive.

1.3. CULTURE HISTORY OF THE AREA

Records of human occupation in Northwestern Ontario date as far back as 7500 B.C. when the first Palaeo-Indian hunters arrived into the area. A very long timespan of culture history is represented by relatively sparse settlement remains, which is further confounded by compressed soil deposition or collapsed stratigraphy (Spiedel, 1989). Human occupation in the Lake of the Woods and surrounding area (Lac Seul and Rainy Lake/River) (Figure 1) spans at least 8000 years, beginning with the Paleo-Indian period followed by the Archaic, Laurel, Blackduck, Selkirk, Cree, Ojibwa and Fur Trade occupations (Dawson, 1978; Reid, 1976). Many important sites have been uncovered, some with important spiritual/religious significance based on artefacts, mounds, or petroglyphs found at or near some sites; and some with important social or economic aspects with the evidence of large-sized villages (Reid, 1976). However, the economic factors allowing for the sustainability of such sites are not well understood.

Reid (1976) argues for the "corridor concept" to explain the locations of sites within the Lake of the Woods area, which is based on three elements: major access routes such as the Winnipeg River, Rainy River, and English River systems, among others; high winds and shallow water in the ice-free months, making it essential to use the channels formed by islands and peninsulas in small crafts; and the outcrops of workable materials that occur from Treaty Island towards Crowduck Lake. Reid (1976) argues that these "corridors" are preferential habitation/camp site locations, and that even though other factors such as spawning grounds or rapids would also have influenced site selection, people often depend on "safe travel" corridors. However, Rajnovich (1984) also argued that the locations of archaeological sites in the area might have been influenced by the locations of wild rice stands, based on the correlation between the locations of modern wild rice and archaeological sites.

Lake of the Woods would have been a major cultural interaction zone due to diverse exploitable ecological zones such as the Boreal and Great Lakes-St. Lawrence forests, as well as the Parkland and Prairie, which lie in close proximity. The Rainy River also gives good access to the Great Lakes and a secondary access to the headwaters of the Mississippi, which is suggested by Reid (1976) as a possible route for trading native copper from Lake Superior; a possible reason for the spread of Laurel mound building; as well as being a major trade route used by French and English fur traders (Reid, 1976). The Warroad River at the southwestern corner of the lake is an access point to the Parkland zone where the Knife River chert would have originated from (Reid, 1976). The Winnipeg River gives access to the Plains, which would have been an important Cree-Assiniboine transportation link during both prehistoric and historic times (Reid, 1976). The English and Wabigoon rivers, running off the Winnipeg Rivers would have given access to the Hudson Bay Lowlands and James Bay (Reid, 1976). Furthermore, Reid (1976) mentions that there are many lakes and rivers connected all throughout the access points previously mentioned that would have served as possible travel routes.

1.4. THE IMPORTANCE OF WILD RICE AMONG NATIVE COMMUNITES

Wild rice has a long history of use among the Ojibway or Chippewa. It occupies a special place for natives, who consider it a gift from the Creator. According to some Anishinaabeg (Ojibwa or Chippewa) beliefs, as glaciers melted and the oceans rose on the East Coast, they were told through a dream to migrate west until they reached a place were food grows on water. The place they reached was the Great Lakes region, where manomin (wild rice or “good berry”) flourishes in the waterways due to the freezing winters, which give the grain the period of dormancy it requires (Forliti, 2006). Even today, wild rice still holds a great importance for the Ojibwa, as food, an economic commodity, and the cultural value it holds (Forliti, 2006). It has also become a very desirable and economically important resource for many people and because of its increased exploitation, the antiquity of its use by native communities has become a much-debated topic, especially when it comes to treaties and claims on this resource (Johnson, 1969a; Rajnovich, 1984). Since wild rice is becoming an important economic food, determining its range and predictability is crucial.

Besides being an important food, wild rice beds provide much of the suitable nursery habitats inland and long shorelines for waterfowl (Stickney, 1896; Vennum, 1988). Species commonly known to live among wild rice stands include mallards, greater and lesser scaup, ring-necked ducks, wood ducks, common golden-eye, buffleheads and blue-winged teal; however many other species also live within wild rice stands. Wild rice also tends to attract large game such as moose (Vennum, 1988).

1.5. MICROFOSSIL ANALYSIS AS A PROXY IN RECONSTRUCTING PAST DIETS AND ENVIRONMENTS IN NORTHWESTERN ONTARIO

Various techniques have been applied to reconstruct past diets such as gas chromatography and stable isotopes. However, these techniques can be problematic when used on their own. Gas chromatography with mass spectroscopy (GC/MS) is a technique that has been applied to archaeological residues in order to identify fatty acids; however, it can be very difficult to differentiate between certain foods consumed (Malainey et al., 1999). Stable isotope analysis is another important technique that has been used to infer about past diets from bones and residues from archaeological sites (Buikstra and Milner, 1991; Katzenberg et al., 1995; Morton and Schwarcz, 2004; Tykot and Staller, 2002). Morton and Schwarcz (2004) estimated that the under-representation of maize in the cooking residues might be because maize was being processed in other ways (corn on the cob or some other prepared form). Hart et al. (2007) suggest that prior knowledge of C3 plants and animals consumed by themselves or together at sites, as well as knowledge of food preparation is necessary in order to fully interpret stable carbon isotope values of cooking residues. Hart et al. (2003) combined phytolith analysis with stable carbon isotopes analysis of carbonized food residues and suggested that depleted ^{13}C cannot be used to indicate the absence of maize in residues since some samples with depleted values ^{13}C contained maize phytoliths (also see Hart et al., 2007). For these reasons, the use of microfossil analysis in reconstructing past diets is recommended.

Pollen, phytoliths and starch granules are some of the microfossils types in plants which survive post-mortem organic decomposition. In particular, pollen and phytoliths have often been employed in reconstructing past environments, while phytoliths and starch granules have been used to reconstruct past diets (Lentfer and Boyd, 1998, 1999, 2000; McAndrews, 1969; Piperno and Pearsall, 1998). This thesis focuses on the use of phytoltihs, which are opal silica casts of epidermal cells in growing plants (Piperno, 2006). Phytoliths are very resilient and can survive for millions of years; recently Prasad et al. (2005) reported grass phytoliths in dinosaur coprolites. Phytolith morphologies have helped in the past to identify domesticates such as maize, squash, and beans from archaeological residues (Piperno and Pearsall, 1998). Maize (*Zea mays*) is one of the few grasses that has been identified based on specific rondel morphology alone (Bozarth, 1993a; Pearsall et al., 2003).

The identification of regional diagnostic phytolith types for the study area has not been attempted; also, diagnostic rondel types for northern wild rice (*Zizania palustris*) have not been reported so far in published literature. By creating a taxonomic key of several local grasses in the study area, the intent is to answer if wild rice (*Zizania* spp.) produces diagnostic rondel phytolith types, as well as determining if the wild grasses in the study area produce types that are similar to the ones described as being diagnostic for maize (*Zea mays*). Furthermore, lake sediment and carbonized food residues are examined to assess the diagnostic potential of wild rice (*Zizania* spp.) rondel types as an additional proxy for paleoenvironmental and paleodiet reconstruction.

Starch granules, although they are not a main focus of this thesis, are also examined. Starch granules tend to be extracted during the processing of carbonized food residues for phytoliths. Since it is expected that maize starch might have been present in the carbonized residues, samples of economically important plants, including wild rice (*Zizania* spp.) with high starch contents were also processed for comparison purposes only. This is an attempt to rule out any types that might mimic the diagnostic grains described for maize.

PART 1: LITERATURE REVIEW

CHAPTER 2: CULTURE HISTORY OF NORTHWESTERN ONTARIO AND THE SURROUNDING AREAS

2.1. INTRODUCTION

This chapter reviews the various cultural traditions that were present in the Lake of the Woods and surrounding area prior to European arrival. The major cultural complexes that are represented in the study area since ~ 2000 B.P. include Laurel, Blackduck, Selkirk, and Sandy Lake. The purpose of this chapter will be to illustrate the characteristics of the cultures mentioned above, their spatial and temporal distribution and their relation with one another, as well as their interactions with other groups outside the study area. Interactions between cultural groups are important, in the sense that some of the cultural practices will evidently have "rubbed off" onto the cultures in the study area.

2.2. THE ARCHAIC TRADITION (6500 – 2000 B. P.)

The Archaic tradition was present in the area (Figure 3) between 6500 to 2000 years ago until the appearance of the Laurel culture (500 to 200 B.C.). The Archaic tradition is associated with large side-notched projectile points, with concave bases, non-diagnostic biface and uniface tools, and some ground stones and copper tools (Hamilton, 2007). Archaeological evidence suggests a hunting and gathering economy for the Archaic tradition. The Archaic people first adopted pottery between 500 and 200 B.C., from which the Laurel people are thought to derive from (Dawson, 1983d).

The presence of wild rice at archaeological sites increases during the Late Archaic-Early Woodland period possibly reflecting a greater dependence on the grain (Lee et al., 2004). It is quite possible that wild rice was consumed long before the invention of pottery in the area either in birch pots or even in lined holes in the ground; since even during the Historic period, birch pots were occasionally used for cooking wild rice (Vennum, 1988). However, if seeds are not recovered at archaeological sites, it can be quite difficult to assess the importance of wild rice in the diet of Archaic people, although soil samples could provide microfossil evidence of the plant.

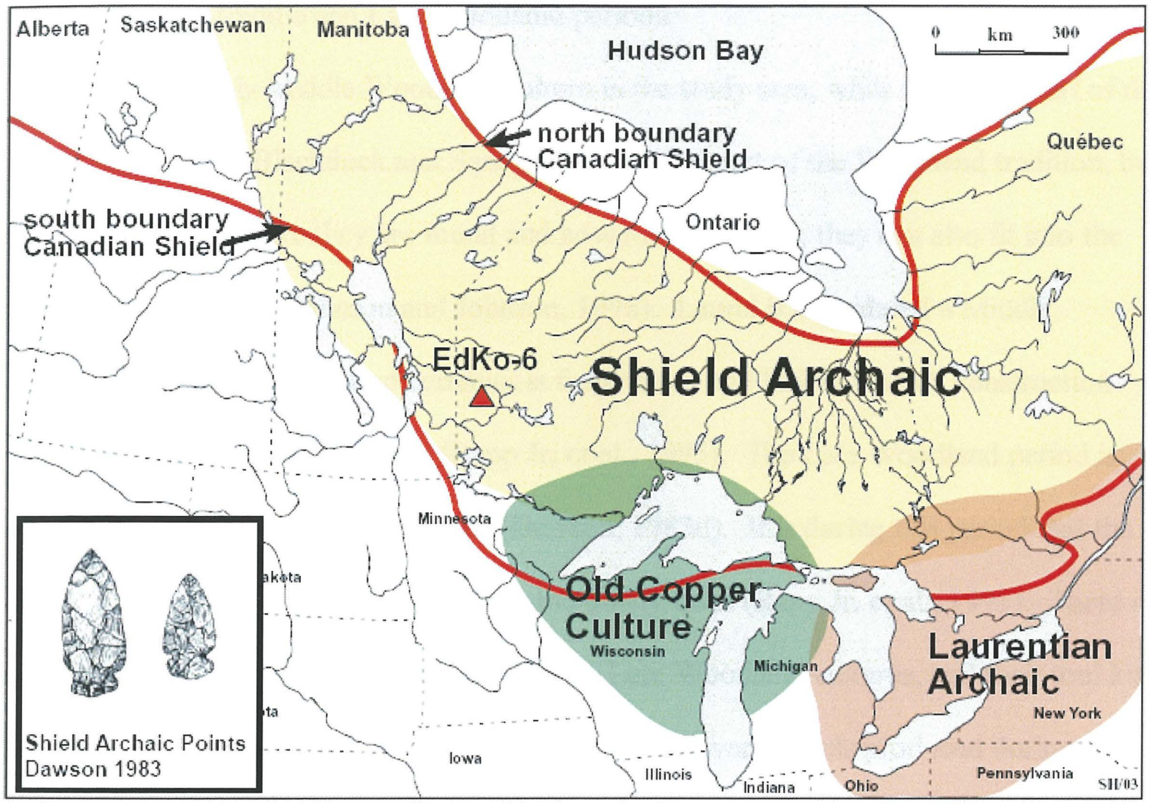

Figure 3. Distribution of Archaic cultures in northwestern Ontario and surrounding areas (EdKo-6 = Rowdy Lake site used in this study) (from Hamilton, 2007).

2.3. THE WOODLAND TRADITION (500 B. C. – CONTACT)

The term Woodland refers to an archaeological tradition that dates from 500 B.C. to A.D. 1200 (later in some areas, i.e., ends during the Historic Period in the Lake of the Woods and surrounding area). The Woodland Tradition is characterized by the appearance of ceramics, burial mounds and small triangular projectile points (bow and arrow) (Rapp Jr. et al., 1995), semi-permanent villages, and possible horticulture (Anfinson, 1997) around 500 B.C. (Dawson, 1983d).

The Woodland tradition is divided into three periods: the Early, Middle and Late Woodland periods. In northwestern Ontario, the Woodland tradition is divided into two: the Initial Woodland period (500 B.C. to A.D. 1200) (McMillan, 1995; Reid and Rajnovich, 1991) and the Terminal Woodland period (700 A.D. to Historic) (Dawson, 1983d); however, they are usually referred to as Middle and Late Woodland periods.

Laurel is the only Middle Woodland culture in the study area, while Selkirk is part of the Late Woodland period. Blackduck and Sandy Lake are also part of the Woodland tradition, but depending on the area where they are found and how they subsisted, they can also fit into the Plains Woodland tradition (Johnson and Johnson, 1998). Laurel is considered a Middle Woodland phase since its associated ceramics is finely made and lacks the thick construction characteristic of Early Woodland types (Rapp Jr. et al., 1995). The Late Woodland period is marked by shifts in ceramic and point styles (Dawson, 1983d). It is during this period that the Blackduck phase appears, followed by Selkirk and Sandy Lake (Rapp Jr. et al., 1995). There is an overlap of 300 years with Laurel and some of the Late Woodland cultures, and their tool kits are similar to the ones associated with Laurel pottery. However, vessels produced during the Late Woodland period are fabric or cord impressed and globular in shape (Dawson, 1983d).

During this period, there tends to be an increase in site frequency and size; however this might be a reflection of what has been recovered so far. Syms (1977) suggests that the Late Woodland period coincided with climatic ameliorations, which marked a shift in populations in the Upper Great Lakes (Dawson, 1983d). Dawson (1983d) suggested that extensive seasonal village sites, which appear during this period, are usually located near natural floral communities where food resources are abundant. Either these Late Woodland cultures developed out of Laurel because of increasing contact with groups to the south or they represent people moving into the area, thus replacing the Laurel people (Dawson, 1983d).

2.4. THE LAUREL PHASE (500 B.C. – A.D. 1200)

2.4.1. Distribution and Cultural Origins

The emergence of the Laurel culture in the southern Boreal forest is thought to occur as early as 300 B.C. (Spiedel, 1989) or 200-150 B.C. (Dawson, 1981; Rajnovich, 1980; Reid and Rajnovich, 1991; Wright, 1967), and perhaps as early as 500 B.C. (Dawson, 1978; Wright, 1967) in the Boundary Waters area (Dawson, 1981; Rajnovich, 1980; Reid and Rajnovich, 1991) to about A.D. 800 (Wright, 1967) or A.D. 1200 (Reid and Rajnovich, 1991; Spiedel, 1989). According to Rapp Jr. et al. (1995), Laurel dates from 100 B.C. to A.D. 1250, but as shown above, both ends of the range are controversial. From the Boundary Waters area, Laurel people are thought to have expanded into Manitoba around A.D. 100 (Dawson, 1981; Rajnovich, 1980).

Laurel appears in Northern Ontario at a time of population expansion and development south of the Great Lakes (Dawson, 1983d). Laurel sites tend to be located along major rivers and at the mouths of rivers emptying into lakes (Dawson, 1983d). Laurel pottery (Figure 4) ranges from east central Saskatchewan (Meyer and Epp, 1990) to west central Quebec in Canada and in the northern portions of Minnesota, Wisconsin, and Michigan in the United States (Dawson, 1983c, 1983d; Mason, 1981) with most sites occurring in the Boreal Forest (Rapp Jr. et al., 1995). Laurel spreads as far south as central Minnesota and as far north as the Hudson Bay Lowlands (Rapp Jr. et al., 1995).

With amelioration in climatic temperatures, the adoption of pottery is seen as a possible means to better exploit new resources, such as wild rice (Johnson, 1969a; Gibbon and Caine, 1980). Especially since pottery would have been an important tool in the parching, cooking, and/or storing of wild rice and other foods. It also has been suggested that the use of pottery was result of diffusion, and that Laurel pottery emerged from the adoption of pottery by Shield Archaic cultures (Hamilton, 1981; Mason, 1981; Syms, 1977; Wright, 1967). Adoption of ceramics by Shield Archaic cultures might be due to the influence of the Saugeen and Point

Penninsula cultures (Figure 4) of southern Ontario (Dawson, 1983d; Mason, 1969; Wright 1967) or a Hopewellian influence (Figure 4) via the Malmo culture of Northern Minnesota (Dawson, 1983d; Wright, 1967). The Hopewellians were intensive foragers that produced exotic art objects, constructed elaborate earthworks and burial mounds, and might have experimented with horticulture (Hamilton, 2007). Dawson (1981, 1983) suggests that it is also possible that Laurel pottery resulted from a northward movement of people representing a blending of Shield Archaic people who adopted pottery, their descendants, and new people from the south.

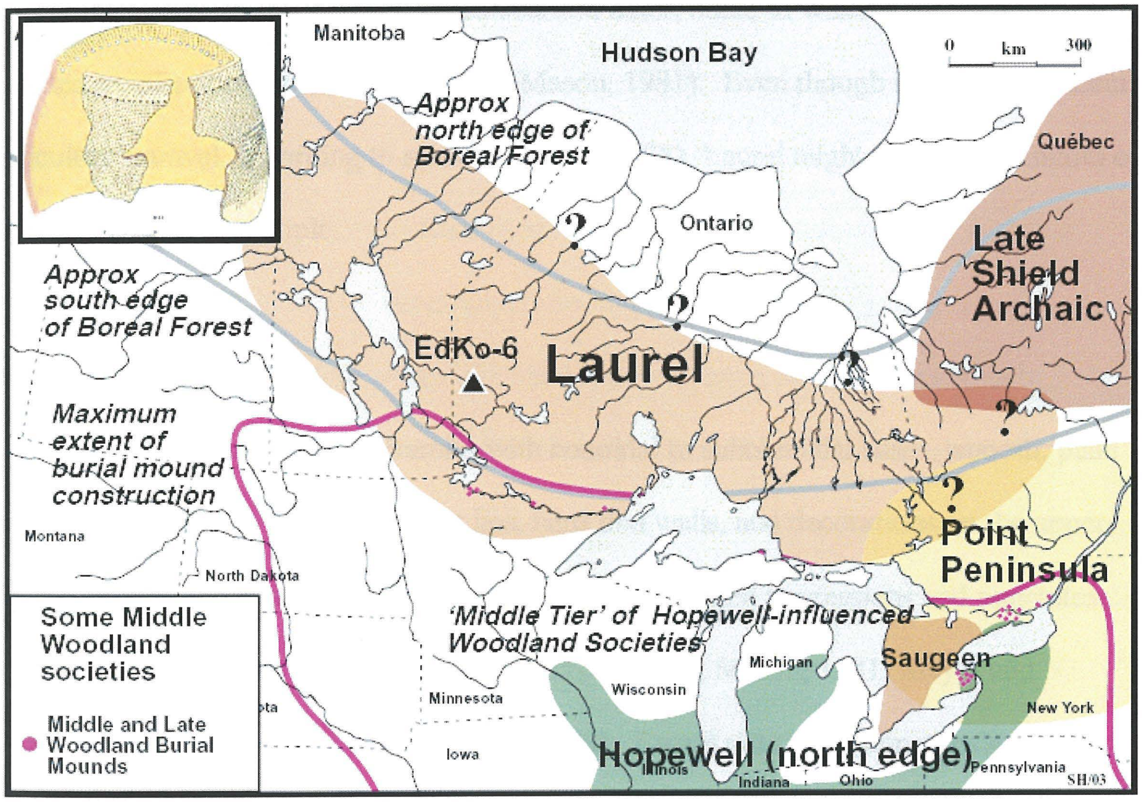

Figure 4. Distribution of Laurel and other Middle Woodland influences on northwestern Ontario (EdKo-6 = Rowdy Lake site used in this study) (from Hamilton, 2007).

According to Buchner (1979), the expansion of wild rice could also be crucial to the northward expansion of Laurel. Based on pollen studies of Minnesota, lake and bog sediments dating to the first millennium B.C. have produced hints of climatic amelioration (Mason, 1981).

Some have argued that there is a link between Laurel ceramics and the spread of wild rice and Conifer-Hardwood Forests (Buchner, 1979; Stoltman, 1973). It has also been suggested that this might have encouraged a northward expansion of wild rice towards the Rainy River area and with it some southern cultural practices, such as mound building (Mason, 1981). However, in conjunction with the Minnesota sequence, the geographical plotting of Laurel types seems to follow the argument that the earliest Laurel sites occur in the south with a northward movement of Laurel populations with the northernmost sites being on average more recent in age (Mason, 1981). Radiocarbon dates from sites only offer some modest support of a south-north migration, since there are only a limited number of radiocarbon dates, some of which indicated that young Laurel sites are also found north of its range (Mason, 1981). Even though the origins of Laurel are difficult to unravel, according to some (Dawson, 1978), Laurel might be the progenitors of the Algonkian-speaking people.

2.4.2. Technology

Laurel is characterized by ceramics with conoidal to subconoidal bases, smooth, plain bodies, straight to slightly flared rims, flat lips, hard thin walls, and decorations on the upper third of the vessels, which includes various stamped and dragged impressions and punctates (Anfinson, 1979; Lenius and Olinyk, 1989; Lugenbeal, 1976; Mason, 1981; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995; Spiedel, 1989). Laurel pots are symmetrically crafted (Mason, 1981) and manufactured by the coiling method beginning at the rim and proceeding to the base (Budak, 1985).

Decorations on the upper portion of the vessel include varying frequencies of "pseudoscallop shell" stamping, incising, dentate, linear and stab-and-drag stamping (Anfinson, 1979; Dawson, 1981, 1983d; Lenius and Olinyk, 1989; Mason, 1981; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995). The decorations were made by pressing a notched tool into the still moist clay to form simple linear, wavy lines or dragged impressions (Dawson, 1983d). Laurel ware is thicker, conoidal, and coarser than Sandy Lake Ware, has pointed lips, coil breaks, and is often elaborately decorated on the rim with different impressions which is not found on Sandy Lake Ware (Lugenbeal, 1976). Pottery types identified for Laurel include: Dentate stamp, Pseudo-Scallop Shell impressed, Bossed, Incised, Plain, Punctate, Cord-wrapped Stick, Dragged Oblique, and Undragged Oblique (Lungenbeal, 1976; Mason, 1981; Stoltman, 1973, 1974).

Laurel vessels are often attributed to different phases based on stylistic attributes: undecorated vessels, and those with dragged and stamp decoration (which produces a distinctive ribbon-like design) are characteristic of Early Laurel sites, while wavy-line pseudo scallop shell stamp occurs in high frequencies in Middle Laurel Sites, and toothed dentate-stamp designs may occur in Late Laurel assemblages (Lugenbeal, 1976). On later Laurel vessels there is a shift from plain to cord treated surface treatment and cord stamp decoration made with a cord wrapped stick (Lugenbeal, 1976). Furthermore bossing on the exterior rim appears to be an earlier trait, while punctates on the exterior rims occurs on Late Laurel sites and that a combination of the two may be indicative of Late-Middle period Laurel (Lugenbeal, 1976). However, this scenario is complicated by the lack of well-dated and well-stratified Laurel sites.

Dawson (1981) divides the Laurel tradition into two phases: an early phase characterized by pseudo-scallop shell ceramics and Archaic-like lithics (200 B.C. to A.D. 500), and a late phase, which he divides into two: an era of population growth and diverse Laurel ceramics (A.D. 500 to A.D. 900), and an era of reduced population and coalescence with a later Terminal Woodland period Blackduck Tradition (A.D. 900 to A.D. 1200). From his study of Laurel ceramics in Northern Ontario, Wright (1967) suggests that Pseudo-Scallop Shell and combined techniques were an early trait while dentate stamp dragged and plain was a late trait.

Three major phases of Laurel have been defined by Stoltman (1973): the Pike Bay Phase (A.D. 100-300), the McKinstry Phase (A.D. 300-500), and the Smith Phase (A.D. 500-900).

During the Pike Bay phase, half of the pots belong to the type of Laurel Oblique (with linear and stab-and-drag stamping), with low percentages of dentate, pseudo-scallop-shell, bossed, or plain vessels, and punctate rims are absent (Mason, 1981; Stoltman, 1973). Laurel ceramics assigned to the Middle Laurel period or McKinstry Phase are found in northern Minnesota (Stoltman, 1973), northwestern and northeastern Ontario (Arthurs, 1986a) and in southeastern (Stoltman, 1973) and northern Manitoba (Lugenbeal, 1976), and possibly in Saskatchewan around the Saskatchewan River delta (Meyer and Hamilton, 1994; Rapp Jr. et al., 1995). McKinstry phase ceramics are characterized by substantial percentages of Laurel Pseudo-Scallop Shell and the boss and punctate subtypes of Laurel Bossed, as well as an increased frequency of punctated rims (Lungenbeal, 1976; Mason, 1981; Stoltman, 1973). During this period Laurel Oblique types are almost obsolete, and the dentate stamped and plain Laurel vessels still aren't popular (Mason, 1981). During the Smith phase dentate stamping and punctates become very popular; there is a decline of pseudo-scallop shell stamping and the making of plain vessels, and there is a resurgence of Laurel Oblique (Mason, 1981; Stoltman, 1973).

The chrono-stylistic scenario described above appear to be localized (Dawson, 1981) and must be evaluated with scepticism. For example, phases that are viewed as temporal or regional complexes in Minnesota depend on the stability of decorative styles on pottery over a long period of time but the relative abundance of ceramic decorative styles changes through time (Buchner, 1979; Hamilton, 1981; Mason, 1981; Syms, 1977). Changes in ceramic habits accompany in part the passage of time but also depend on geographic location. During the same period one type can dominate in one area and be very minor in another (Mason, 1981).

The Laurel tool kit includes bone tools such as cut beaver incisors or bird bone awls, "snowshoe" netting needles, notched net-sinkers, axes, adzes, toggle-head harpoons, conical (barbless) harpoon points, stemmed/notched projectile points, end-scrapers, native copper tools consisting of awls, gorges, barbs, chisels, and pressure-flakers produced by cold hammering

(Dawson, 1980, 1983c, 1983d; Mason, 1981; McMillan, 1995; Meyer and Epp, 1990; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995; Spiedel, 1989; Stoltman, 1973; Wright, 1967). During the development of Laurel, the appearance of the bow and arrow replaces the spearthrower (Wright, 1995). Copper beads, pendants or other ground or polished stones (Mason, 1981; Wright 1967) as well as discoidal beads of marine shell (Stoltman, 1973; Webster, 1973) are also found at Laurel sites. However, there is a decrease of bifacial knives and ground stone tools compared to the Archaic period, and an increase in scraper forms, utilitarian or ornamental copper items, and red ochre nodules found at archaeological sites (Wright, 1995).

2.4.3. Subsistence

It is very difficult to reconstruct Laurel subsistence practices since almost all bones are destroyed due to the highly acidic soils of the area (Wright, 1995). Good faunal assemblages are only reported from a few sites such as Heron Bay in Ontario due to the neutralizing effects of the wood ashes (Arthurs, 1986b; Wright, 1967). A broad-spectrum hunting and gathering economy is reflected from the artifactual evidence from Laurel sites (Hamilton, 2007; Rapp Jr. et al., 1995). Evidence of charred and uncharred interiors suggests that the vessels were used both for cooking and storage (Dawson, 1983d). Laurel people are thought to have employed seasonally available resources implying movements between the Mixed Conifer-Hardwood and Parkland biomes in Minnesota, as well as a reliance on diffuse resources in eastern and northern Manitoba and Northwestern Ontario.

Beaver and moose appeared to be the most important animals besides caribou, bear, muskrats, woodchucks, chipmunks, squirrel, porcupine, wolf, dog, marten, fisher, striped skunk, river otter, lynx, white-tail deer, bobcat, hare, various birds, and bison in some areas (Dawson, 1983d; Stoltman, 1973; Wiersum and Tisdale, 1977). While fish bones and scales are only found in small quantities, most likely due to poor preservation, fishing was most likely very important.

Sturgeon, northern pike, whitefish, char, walleye, and suckers appear to have been consumed by the Laurel people (Dawson, 1983d; Wright, 1967). During spring and early summer, people would have gathered to exploit fish in large concentration; during the autumn, spawning fish and wild rice would have been readily available; during the winter, they would have split into small groups to survive on land mammal resources (Hamilton, 1981). Fishing is thought to have played a crucial role in boreal forests adaptations, especially in sites where the number of species living in or near aquatic settings is greater than those living in terrestrial settings (Tisdale, 1977).

Valppu (1989) has suggested that wild rice was an important part of the diet of the Laurel people. According to Ford and Brose (1975), wild rice appears in archaeological sites as early as 500 B.C. in northern Michigan, and a date of A.D. 235-325 was obtained from a Laurel wild rice parching pit at the Big Rice site in Minnesota (Valppu, 1989; Valppu and Rapp, 2000). Compared to sites south of the Upper Great Lakes; there is no macrofossil evidence to support that Laurel made use of local plant resources (Dawson, 1983d).

2.4.4. Cultural Practices and Regional Interactions

Laurel burial mounds containing bundle burials (Dawson, 1983d; Meyer and Hamilton, 1994) are found in Ontario between Lake Superior and the Manitoba border (Figure 4), particularly along the Rainy River (Anfinson, 1979; Lenius and Olinyk, 1989; Mason, 1981; McMillan, 1995; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995). Excavation of the Armstrong Mound (dated to approx. 1000 years B.P.) at the Long Sault site revealed the remains of thirteen individuals in disarticulated bone bundles covered with red ochre. The Laurel mound is 35 metres in diameter and 7 metres high, making it the largest burial mound in Canada (McMillan, 1995). A Hopewell-style platform pipe was also found in the mound suggesting a possible Hopewell influence of mound building on the Laurel culture (Mason, 1981; McMillan, 1995). Wright (1967) argues that due to the specific distribution of Laurel mounds along the

Canadian border, especially around the Rainy River area, reflects a direct influence of the Hopewell Tradition, which was adopted by Laurel. Arthurs (1986b) has suggested that mound building only would have been constructed due to larger population densities supported at large fishing sites.

A Laurel mound at the MacGillivray site, located on an island in Whitefish lake near Thunder Bay, Ontario was dated to approximately 200 B.C. to A.D. 300 (Dawson, 1980). It is one of the oldest dated Laurel mounds in Ontario and the site is located near modern wild rice stands and the lake is an excellent source of fish and other aquatic plants (Dawson, 1980). Polished slate pendants from the MacGillivray site, also suggests Hopewellian influence (Dawson, 1980).

Mortuary practices for Laurel suggest complex preparations of the body (Lungenbeal, 1976; Stoltman, 1973, 1974), including post-mortem dismemberment and bone deformation (Torbenson et al., 1994), clay plugs in the eye sockets, the use of red ochre, and the differential burial of body parts (Rapp Jr. et al., 1995). Torbenson et al. (1992) examined punctured human bones from the Laurel culture from Smith Mound Four in Minnesota. They suggested that the bones were punctured prior to burial on the basis of group affiliation or perhaps may have involved ideas of spirit release. Exotic artifacts such as bird stones (abstract stone carvings), usually found in Hopewellian sites, have also been recovered from Laurel mounds (Dawson, 1983c). Wright (1967) suggests that ground and perforated bear canine found with an infant, rather than an adult burial also reflects a Hopewellian relationship. Wright (1995) argues that the elaborate mound ceremonialism might have passed from the Hopewell tradition to Laurel through the Malmo tradition. While the absence of grave offerings directly associated with the deceased and the addition of red ochre might reflect Laurel values, Wright (1995) says that traits found in Laurel such as brain and longbone marrow removal reflects Hopewellian influences.

The majority of Laurel sites have been found in Ontario, they are usually small campsites yielding evidence of seasonal occupations of one or two families temporarily encamped at a good hunting or fishing spot which may have persisted over a period of several seasons (Mason, 1981). Large sites with high artifact frequencies could represent warm season base camps with large populations while small sites with low artefact densities are thought to be wintering sites or specialized activity areas (Rapp Jr. et al., 1995). It has been suggested that the use of diffuse resources might have been determined by the seasons Laurel people would have frequented various regions or environmental zones (Upper Great Lakes and Lake Forest biomes; Mixed Conifer-Hardwood and Parkland biomes; and the Boreal Forest biome) (Buchner, 1979; Syms, 1977) and the types of social organizations (i.e., specialized bison hunters) (Hamilton, 1981).

Oval Laurel dwellings seem to occur at various sites in the Lake of the Woods Area such as the Ballysadare site (DkKp-10), the Bundoran site (DjKn-5), the Fisk site (DlKp-1) and the Meek site (DjKp-3) (Rajnovich, 1980; Reid and Rajnovich, 1985). These houses tend to be approximately 6-8 m long and 3-5 m wide (Reid and Rajnovich, 1985) and typically have a central hearth or hearths, storage pits and activity areas (Dawson, 1983d; Reid and Rajnovich, 1985). The Ballynacree site in Kenora provided evidence of a Laurel village consisting of three oval-shaped (possibly dome-shaped) houses, sheltering a population of about thirty people (McMillan, 1995).

Ceramic sherds exhibiting both Laurel and Blackduck traits, has lead some (Lugenbeal, 1976) to suggest that interaction existed between these people or, at the very least, that they shared a common ancestry. Excavations of Laurel at the Heron Bay site yielded important information on long distance trade. Many exotic goods were found such as obsidian from Wyoming, polished stone gorgets, shell from southern Manitoba, and pottery from the Saugeen culture of southern Ontario, suggesting Hopewellian influences (Dawson, 1976a; McMillan, 1995). Laurel people are also thought to have interacted with the Avonlea culture in Saskatchewan (Meyer and Epp, 1990).

2.5. THE BLACKDUCK PHASE (A.D. 800 – 1650)

2.5.1. Distribution and Cultural Origins

The Blackduck phase is part of the Late Woodland period, or Terminal Woodland period, in Canada (McMillan, 1995). In Minnesota, Blackduck appears between A.D. 600 and A.D. 800 with the disappearance of Laurel in the area (Rapp Jr. et al., 1995). According to Reid (1978), Blackduck people occupied the Lake of the Woods Area from about A.D. 950 to A.D. 1650. However, some have argued that the Blackduck phase began around A.D. 650 (Dawson, 1983d) or A.D. 800 (Cooper and Johnson, 1964) and would have ended around A.D. 1650 (Syms, 1977) or A.D. 1750 (Dawson, 1976b). There appears to have been an era of coalescence between the Blackduck and Laurel for a few centuries until about A.D. 1000 or slightly later based on ceramic sherds exhibiting traits from both phases (Lenius and Olinyk, 1989; Lugenbeal, 1976).

Blackduck occupations in North America (Figure 5) are known to extend south in Northern Minnesota, to the east in the Eastern Lake Superior area, to the north as far as Red Lake in Northwestern Ontario and as far west as Lake Winnipegosis in Manitoba (Rajnovich, 1980). However, they also appear in western Quebec, as well as across northern Ontario, throughout southern and central Manitoba, with some vessels appearing in east-central Saskatchewan (Hamilton, 2007; Meyer and Epp, 1990). Dawson (1981, 1983d) explains that the Blackduck tradition is seen as southern population who rapidly spread across northwestern Ontario, which might coincide with climatic amelioration (A.D. 700 to A.D. 900). Based on archaeological and historic distributions, and from skull measurements, it has been argued that the northern Blackduck may be related to the Ojibwa populations (Dawson, 1978, 1981, 1983d, 1987; Mason, 1981), while the southern Blackduck may be related to the historic Sioux or Assiniboine (Mason, 1981).

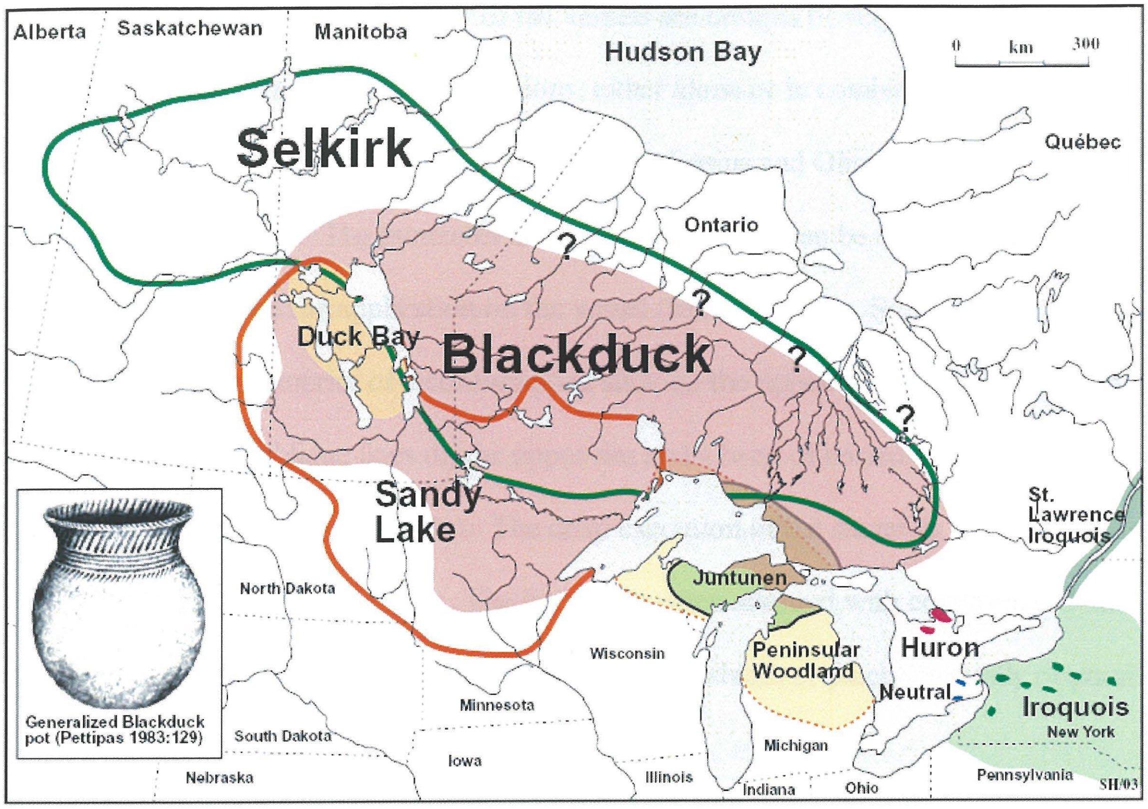

Figure 5. Late Woodland and other Late Precontact cultures (from Hamilton, 2007)

2.5.2. Technology

Blackduck is characterized by distinctive decorative traits on thin-walled, globular vessels with flared rims, round shoulders, a moderately constricted neck, and a very broad, splayed lip (Dawson, 1983d; Lenius and Olinyk, 1989; Mason, 1981; Meyer and Hamilton, 1994; Walde et al., 1995). The exteriors of the vessels bear vertically-oriented textile impressions produced either by a cord wrapped paddle (paddle and anvil) or a textile bag (fabric-mold technique) (Lenius and Olinyk, 1989; Mason, 1981; Meyer and Hamilton, 1994). In some cases, they may bear net impressions, and smooth surface finishing or brushed surfaces that are restricted to the neck and rim (Mason, 1981). Three sizes of Blackduck vessels were manufactured: large and medium utilitarian vessels and small juvenile or mortuary vessels (Dawson, 1983d).

Found on the rim or neck exterior of the vessels are designs of very tightly spaced vessel-encircling rows of cordwrapped-stick impressions, either alone or in combination with a single row of punctates or very rarely bosses (Dawson, 1983d; Lenius and Olinyk, 1989; Mason, 1981; Meyer and Hamilton, 1994). The punctates are usually round but can be rectilinear or hemiconical resulting from the application on the vessel (Mason, 1981). Some vessels have a short vertical or diagonal imprint of a cordwrapped stick on the upper rim (Mason, 1981). A typical combination was oblique lines on the upper rim and a band of horizontal lines below, sometimes with punctates (Mason, 1981). The crisp execution of the stamping and punctuating sets it from other wares (Mason, 1981). The lip itself is often adorned with cordwrapped-stick impressions oriented obliquely, in a criss-cross or chevron fashion, or placed centrally or parallel to the vessel wall (Mason, 1981).

Ceramic types of Blackduck include: Waskish Vertical Cord and Punctate (Rajnovich, 1980), Osufsen Cord and Punctate, Nett Lake Cord and Punctate, Nett Lake Plain, and Schocker Cord Impressed (Evans, 1961b). Duck Bay ware is usually lumped with Blackduck. This type is characterized by straight or S-shaped rims set on angular necks and angular shoulders, which are sometimes decorated. The vessel exteriors bear a smoothed exterior. One type of Duck Bay ware has a minimum of three rows of punctates on the rim exterior (Duck Bay Punctate). The other has shallow closely spaced punctates on the rim exterior, extending onto the lip (Duck Bay Notched Lip), and the last is characterized by the lack of decorations, while maintaining the overall vessel shape (Duck Bay Undecorated) (Meyer and Hamilton, 1994). Duck Bay ware ranges from a number of sites on Lakes Winnipegosis and Manitoba as well as Lake Winnipeg (Figure 5). Duck Bay ware has been found out of its range in small quantities in Saskatchewan, Northern Minnesota and Northwestern Ontario (Meyer and Hamilton, 1994). Unfortunately the time span of Duck Bay ware is not well established (Meyer and Hamilton, 1994). Even though Duck Bay is often lumped with Blackduck, some (Lenius and Olinyk, 1989) have suggested the lumping of these ceramics under another classification called the Rainy River Composite.

In northern Minnesota, an early and late phase of Blackduck was distinguished, with cordmarking being an early surface finish whereas fabric-impression was a later trait, and interior rim decorations occurring in the early phase and nodes or bosses occurring the later phase (Mason, 1981). Undecorated rims and the use of cordwrapped-stick impressions or punctuations are also characteristic of the late Blackduck phase (Mason, 1981).

The Blackduck tool kit is mainly composed of small triangular and side-notched projectile points (reflecting a bow and arrow technology (Walde et al., 1995)), oval and lunate knives, end and side scrapers, trapezoidal end scrapers, thumbnail scrapers, awls, unilateral barbed harpoons, socketed bone projectile points, bone spatulas, tubular-shaped drills, fleshers, awls, fishhooks, and beaver incisor gouges (Anfinson, 1979; Dawson, 1983d; Evans, 1961b; Lugenbeal, 1976; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995). Easy access to copper of western Lake Superior is evident from the numerous knives, awls, fishhooks, gorges, and beads of this material found at Blackduck sites (Anfinson, 1979; Mason, 1981; McMillan, 1995). Besides tools, other items such as beads and tubular pipes are also found at Blackduck sites (Dawson, 1983d; Lugenbeal, 1976; Meyer and Hamilton, 1994).

2.5.3. Subsistence

Subsistence economy of the Blackduck phase is thought to be similar to Laurel – they are thought to be broad-based hunter-gatherers (Hamilton, 2007). However, the subsistence strategies of Blackduck people are varied, depending if they were living in the Boreal Forest or the Plains (Hamilton, 1982; Hamilton et al., 2007; Nicholson, 1996). Blackduck occupations such as the Stott, Gompf, and Brockinton sites in the southern Manitoba parklands provides clear evidence that some groups focused on the exploitation of plains bison herds (Hamilton, 1982; Hamilton et al., 2007; Meyer and Hamilton, 1994; Nicholson, 1987; Walde et al., 1995). Based on the evidence provided by the bones, fish and animals such as moose, beaver, caribou, bear, and waterfowl were important resources that the Blackduck people exploited in the Boundary Waters region of Minnesota and Ontario (Anfinson, 1979; Dawson, 1983d; Gibbon, 1994; Nicholson, 1996). Due to the location of sites near modern wild rice stands in the area, some claim (Gibbon, 1994; Rajnovich, 1984; Walde et al., 1995) that wild rice might have been an important food source; however its importance has not been demonstrated (Rapp Jr. et al., 1995). For example, the Stott site in Minnesota, has been described as a Blackduck wild rice harvesting site where Sandy Lake Ware has also been found (Johnson, 1969a).

2.5.4. Cultural Practices and Regional Interactions

Like Laurel, many Blackduck populations centred predominately along the Minnesota-Ontario border. They continued to make burial mounds, although a shift is subsequently seen to the adoption of flexed inhumations (Dawson, 1983d; Mason, 1981; Meyer and Hamilton, 1994). Blackduck mounds tend to be smaller than Laurel mounds (Lungenbeal, 1976; Mason, 1981). Their distribution is much like Laurel following the Rainy River, although they are also found in southern Manitoba (Mason, 1981). Some of the burials appear to be more complex than Laurel, with bundle bones covered in red ochre, small pottery vessels (Mason, 1981) that were frequently placed with the dead, and in some cases the back of the skulls have been removed, the eye sockets are filled with clay and shell beads are inserted (Dawson, 1983d; Mason, 1981; McMillan, 1995). Interestingly, dogs were occasionally buried with or near the human remains (Dawson, 1983d; Mason, 1981). Copper beads and bear canine ornaments have been associated with Blackduck (Evans, 1961b; Lungenbeal, 1976; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995) might also have some religious significances.

Selkirk vessels are commonly found in Blackduck sites suggesting that interactions between the two certainly occured (Mason, 1981). According to Mason (1981) there is a presence of foreign vessels at many Blackduck sites. Plain, grit-tempered Oneota-like pots with ouflaring rims and crenelated lips; typically found in the upper Michigan peninsula and in northern Wisconsin, are known to have been found in association with Blackduck ceramics (Mason, 1981). Iroquois-like ceramics are also found in Blackduck sites (Mason, 1981). Triangular arrowheads and similar kinds of chipped-flint and bone and antler tools reported from the Heins Creek complex, the Lakes phase, and the Effigy Mound culture are found at Blackduck sites (Mason, 1981). Blackduck ceramics have also been found in association with other wares such as Saskatchewan Basin Complex ceramics, shell tempered ceramics and Middle Missouri ceramics at sites such as the Lovstrom site in southern Manitoba (Nicholson, 1988). However, it is difficult or even impossible to tell if ceramics from other cultures represent contact during the Blackduck occupations of the sites or a different occupation of groups from which the exotic materials belong to.

Many people have suggested that Blackduck might have developed from Laurel (McMillan, 1995; Ossenberg, 1974). Buchner (1979) proposed that Blackduck replaced Laurel due to the differences in burial practices by intrusive Blackduck burials in Laurel mounds, and the changes in pottery style from Laurel conoidal, smooth surfaced pots to Blackduck globular, corded surfaces, and ceramic making technology, which would suggest population replacement (Rapp Jr. et al., 1995). However, Johnson (1969a) suggested that the use of wild rice as a staple was a significant development in the Upper Mississippi Valley, which by about A.D. 800 resulted in a population surge that caused a shift from nomadic patterns towards the establishment of permanent villages. This shift could have caused an increase of regular contacts and relationships between various communities, which might explain why there are so many similarities between different contemporaneous groups such as the Blackduck and Arvilla or the Blackduck and Kathio in Minnesota (Ossenberg, 1974). Thus, transitions between Laurel and Blackduck may be caused by interactions with each other, instead of one emerging from the other. Although there seems to have been continuity between Laurel and Blackduck because of common ceramic decorative designs, Dawson (1983d) has argued that the manufacturing techniques are different enough negating the concept of transition between these two cultures.

McMillan (1995) suggests that since Blackduck pottery is mixed with other styles, this would suggests that women, who were the potters in historic times, joined their husband's band upon marriage, and if marriage took place over long distances, it would account for the number of different styles produced by a single group. Mason (1981) follows a similar argument suggesting that due to the great importance of hunting in a sparsely inhabited country, it would have made sense for the men to recruit wives from sometimes far-distant places resulting in wide-ranging marital ties that might explain the appearance of foreign vessels in Blackduck sites.

There is some debate whether the Blackduck people are most likely related to the Ojibwa or the Sioux based on their distribution. However, a number of Blackduck sites in Ontario are known to have produced European goods suggesting a continuous presence of the Ojibwa in the area until the Historic period (Dawson, 1983d).

2.6. THE SELIRK PHASE (A.D. 850 – 1750)

2.6.1. Distribution and Cultural Origins

The Selkirk phase is thought to have emerged as early as A.D. 850 or perhaps as early as A.D. 700 (Arthurs, 1995) and flourished until approximately A.D. 1500 or perhaps up to the post-contact period (Meyer and Hamilton, 1994) around A.D. 1600 or 1750 (Dawson, 1983b, 1983d). Selkirk ranges from the forests of western Saskatchewan (Meyer and Epp, 1990) and east to Northern Lake Superior in its northern range and southeastern Manitoba and adjacent Ontario and Minnesota in its southern range (Figure 5) (Dawson, 1983d; Meyer and Russel, 1987).

Selkirk is also referred to as the Northwestern Algonkians based on the areas where most sites are found; however, they can be found south of their range, mixed with Blackduck pottery (Dawson, 1983d). According to Rajnovich and Reid (1977, 1978), Lake of the Woods was a major occupation zone for the Selkirk culture, with considerable interaction between Selkirk and Blackduck pottery makers, and Selkirk and Sandy Lake pottery makers.

Selkirk is distributed from northwestern Ontario, across Manitoba and into northeastern Saskatchewan (McMillan, 1995). Based on this distribution, the Selkirk people are thought to be the progenitors of the Cree (Dawson, 1978; MacNeish, 1958; McMillan, 1995; Meyer, 1978; Syms, 1977). A Clearwater Lake type vessel made by a Cree woman 500 years B.P. reported by Reid and Ross (1981), seems to support this assumption.

Like Blackduck, Selkirk ceramics are thought to have developed out of Laurel given that some vessels have mixed Laurel and Selkirk attributes (Dickson, 1980; Pollock, 1975). However, there are many problems with these assumptions since treating pots like people is unwise. There are many reasons why one ceramic type can bear some of the decorative traits of another. Diffusion or parallel innovation could explain why some ceramic types have traits similar to another.

2.6.2. Technology

Selkirk is characterized by globular vessels with constricted necks, excurvate or flared rims, and smoothed fabric impressions present over the whole of the vessel exteriors (the weaving of the fabric creates deep indentation on the pottery where the weaves cross) (Meyer and Hamilton, 1994) with finely textured tempering (Arthurs, 1995). They tend to be plain with sparse decorative punctates and occasional cord-wrapped impressions (Dawson, 1983d). Selkirk ceramics also include bowls and plates as well as pots (Dawson, 1983d). Selkirk vessels are fabric impressed and are thought to have been formed by pressing small pieces of clay into a textile mould (Arthurs, 1995). The paddle and anvil method is another technique thought to have been used to construct Selkirk vessels (Dawson, 1983d). A Selkirk vessel recovered from the waters of Lake Superior demonstrated that it was fabric impressed, built from the base up, by the addition of wide strips of clay to the outside of the vessel wall overlapping like shingles on a roof, had coarse grit tempering, and a strip of clay was added to strengthen the neck (Arthurs, 1995).

One variant of Selkirk is Clearwater Lake Punctate (Hlady, 1970); another is Winnipeg Fabric Impressed that can be divided into three types: Alexander Fabric Impressed, Sturgeon Falls Fabric Impressed, and Sturgeon Punctate (MacNeish, 1958). The latter three are thought to belong to the Selkirk Focus by some (Dawson, 1983b); however others have made the case to keep them as separate entities (Meyer, 1978). Winnipeg Fabric Impressed and Clearwater Lake Punctate are known to date to A.D. 1350 to 1750 (Dawson, 1983b; Hlady, 1971). Alexander Fabric Impressed types are thought to occur as late as the seventeen or the eighteen-century (Rajnovich, 1983a).

The nonceramic portions of Selkirk assemblages are very similar to those described for Blackduck (Meyer and Hamilton, 1994). Selkirk lithics include: corner-notched, side-notched and Eastern Triangular points, grooved mauls (Hlady, 1970), end scrappers, bifacially flaked knives, axes (celts), hammerstones, grinding stones, anvils, abraders, bone tools such as awls, flaking tools, tubular beads, fleshers, and arrowshaft straighteners (Dawson, 1983d).

2.6.3. Subsistence

Selkirk sites are often found in the vicinity of modern wild rice stands (Meyer and Hamilton, 1994). Selkirk people are thought to have subsisted on wild rice during the winter, as well as some hunting and fishing during the spring and fall; however the subsistence and settlement patterns of the Selkirk people are not well known (Meyer and Hamilton, 1994). Faunal remains found at Selkirk sites include beaver, moose, caribou, sturgeon, muskrat, fisher, sturgeon, sucker, loon, and turtle (Rajnovich, 1983a; 1983b). During the spring and early summer spawning fish would have been an important resource for the Selkirk people which can be inferred by the presence of sites along the banks of main streams for good fishing (Meyer and Epp, 1990).

2.6.4. Cultural Practices and Regional Interactions

Some rock paintings and boulder construction, which probably served a religious function found near some sites, are thought to be associated with Selkirk (Dawson, 1983d); however it is difficult or even impossible to prove this assumption. Evidence of possible village occupations is inferred from house structures that were associated with Selkirk ceramics at the Spruce Point site in Northwestern Ontario (Rajnovich, 1983a, 1983b). Although burial mounds are not associated with Selkirk, the presence of subterranean structure containing mass burials, have been suggested (Rajnovich and Reid, 1977, 1978).

Because of their distribution, it is thought that the Selkirk and Sandy Lake people might have come in contact with each other (Figure 5). This would explain why some Sandy Lake vessels were classified as Selkirk in the past since they are both fabric impressed, the upper portion of the vessel is not always highly decorated and can be smooth (Meyer and Hamilton, 1994). Selkirk and Blackduck vessels are also often found together at some sites (Dawson, 1983d). McMillan (1995) suggests intermarriage for the explanation of Selkirk and Blackduck being found at the same site, suggesting that intermarriage over long distances occurred.

Meyer and Epp (1990) report evidence of Selirk-Mortlach interactions in Saskatchewan since Mortlach influences on Selkirk vessels which is referred to as the Pehonan complex, Mortlach vessels present at Selkirk sites, or vice versa, and obsidian found in Selkirk sites which they would have obtained from people to the south. Mortlach Aggregate sites can be found from northeastern Montana and northwestern North Dakota to southern Saskatchewan (Meyer and Epp, 1990). Mortlach is characterized by well made ceramics (somes that share attributes with that of the Middle Missouri types), have plains side-notched projectile points, rectilinear and semilunar bifaces hafted in bone handles similar to those made in Middle Missouri villages, ice gliders, and are seen as specialized plains bison hunters (Meyer and Epp, 1990).

2.7. THE SANDY LAKE COMPLEX (A.D. 950 – 1750)

2.7.1. Distribution and Cultural Origins

Sandy Lake Ware appears around A.D. 1000 and perhaps A.D. 950 to A.D. 1750 (Meyer and Hamilton, 1994). Because of misidentification (often being labelled as Selkirk) in the past (Meyer and Hamilton, 1994), or referred to as Ash Rapids Corded (Reid and Rajnovich, 1980), the extent of Sandy Lake ware was not well understood, but lately Taylor-Hollings (1999) has provided a revision on the extent of its distribution (Figure 5). Sandy Lake ware is found in sites in northwestern Wisconsin, north and central Minnesota, eastern North Dakota, northwestern Ontario and southern Manitoba (Taylor-Hollings, 1999). Taylor-Hollings (1999) mentions that wares similar to Sandy Lake Ware were reported in Saskatchewan, and Walde (1994) suggested that Mortlach pottery might represent a continuation of the Psinomani culture in central Saskatchewan, northeastern Montana, and northwestern North Dakota. Anfinson (1979) also suggests that the Sandy Lake culture might be related to protohistoric Eastern North Dakota and/or Assiniboine and may be related to the Sioux (Birk, 1977b) that occupied the Northern Plains.

2.7.2. Technology

The Sandy Lake complex is characterized by simple, globular shapes with slight neck constrictions and nonexistent shoulders. The rims are usually straight or slightly S-shaped (Meyer and Hamilton, 1994) and the walls are very thin and consist of a laminated paste (Taylor-Hollings, 1999). Decoration is sparse, generally consisting only of notches on the inner corner of the lip, although trailed lines also occur, some vessels also have interior rim or neck punctates which produced exterior bosses (Arthurs, 1978; Taylor-Hollings, 1999). The exteriors are usually vertically cord impressed, although smooth exteriors are not uncommon, and in the southern portion of its range it is usually shell tempered (a common Mississippian trait) while in the northern portion it is grit tempered (Meyer and Hamilton, 1994; Rapp Jr. et al., 1995; Taylor-Hollings, 1999).

Besides being grit tempered, vessels produced in the northern range of Sandy Lake Ware (Northwestern Ontario and southeastern Manitoba) also differ in other ways: they do not have smooth surface finishes; they have a row of exterior punctates, some excurvate rim profiles; and different decoration methods (Rapp Jr. et al., 1995). Sandy Lake Ware is divided into four types: Sandy Lake Smooth (Birk, 1979), Sandy Lake Corded (Cooper and Johnson, 1964), Sandy Lake Stamped (Simple and Checked) (Birk, 1979; Peterson, 1986; Rapp Jr. et al., 1995) and Sandy Lake Obliterated (Taylor-Hollings, 1999). The Corded type of Sandy Lake Ware is thought to have been made by using a cord wrapped paddle on the exterior, while the typical parallel vertical textile impressions are thought to have been applied by making the vessel in a textile bag and may account for the thinness of some vessels (Goltz, 1991; Taylor-Hollings, 1999).

Sandy Lake ceramics are often associated with small triangular projectile points, bifaces, scrapers and utilized flakes (Birk, 1977a; Michlovic, 1987), harpoons and fishhooks in Eastern Woodland and Boreal Forest sites, and a few modified bison scapulas in southern Manitoba characteristic of the Oneota phase (Birk, 1977b).

2.7.3. Subsistence

The makers of Sandy Lake Ware are thought to have subsisted on hunting, wild rice harvesting and perhaps maize, as reported from the Shea site (Thompson and Mulholland, 1994). The people who made Sandy Lake Ware are considered to be part of the Psinomani culture (meaning 'wild rice gatherers', a Dakota (Siouan) term used by Gibbon (1994)). Sites associated with Psinomani components often occur where wild rice grows today (Johnson, 1969a; Taylor-Hollings, 1999); however they are not always found where this plant grows. Sites with evidence of Sandy Lake Ware can also be found in areas where wild rice does not grow at all or very little where (Northeastern Grasslands and Aspen Parklands) bison hunting was the primary focus (Taylor-Hollings, 1999).

Wild rice is thought to have been an important part of Sandy Lake economy because of grains found embedded in the pottery and sites located near ricing lakes, as well as ricing jigs/threshing pits that have been found on sites (Arthurs, 1978; Birk, 1977a, 1977b; Rapp Jr. et al., 1995), and faunal remains typical of species harvested in aquatic environments (Birk, 1977b; Rapp Jr. et al., 1995). Johnson (1969a) suggested that Sandy Lake Ware vessels were used for cooking and parching wild rice, given that many sites are found near modern stands of the plant.

Gibbon (1976) noted that one wild rice grain was found in a refuse pit at the Old Shakopee Bridge site in Northern Minnesota where Sandy Lake ceramics were found; however it was lost before analysis. Since the Middle and Late Woodland components were mixed, the cultural affiliation of the seed was unclear, even though the author suspects it is of Late

Woodland origin (Gibbon, 1976). Other wild rice evidence from this site includes small clay-lined pits associated with Sandy Lake Ware, which Johnson (1969b) and Gibbon (1976) identifies as "ricing jigs".

2.7.4. Cultural Practices and Regional Interactions

Sandy Lake Ware is often associated with small seasonally occupied wild rice harvesting belts or campsites and occasionally villages or burials (Birk, 1977a; Michlovic and Schneider, 1993). Two types of burial mounds have been associated with Sandy Lake: small conical mounds and intrusive burials into Blackduck mounds (Birk, 1977a). Burials are primary and flexed, in shallow pits with associated mortuary vessels (Birk, 1977a, 1977b). Burials in middens or other habitation deposits are thought to be more common with mounds reserved for people of higher status (Birk, 1977a).

Sandy Lake Ware has been found in sites with other contemporary archaeological cultures such as Selkirk, Blackduck, Duck Bay, Bird River, Clam River focus, Vickers focus, Northeastern Plains Village and Oneota (Taylor-Hollings, 1999). Wascana ware or Mortlach phase and Saskatchewan Basin complex may also be pottery wares related to Sandy Lake Ware (Taylor-Hollings, 1999). Some Sandy Lake Ware sites have also contained some postcontact artefacts (Arthurs, 1986b; Peterson, 1986). Intermarriage has been proposed to explain the small numbers of Sandy Lake Ware vessels at sites where it is not the major occupation (Taylor-Hollings, 1999).

Evidence of trade has been stipulated for Sandy Lake Ware due to exotic lithic materials found in sites such as Knife River Flint (Taylor-Hollings, 1999). It was noted by Cooper and Johnson (1964) that the shell temper in Sandy Lake Ware are finely ground whereas the shell temper of Oneota vessels from the same region consist of larger particles. They also noted that shell tempering was found in small amounts on the interior and exterior of the vessels. Imported lithics such as obsidian are often found in Sandy Lake assemblages (Taylor-Hollings, 1999).

At the Duthie site, Sandy Lake Ware has been found with ceramics associated with the Northeastern Plains Village Tradition (suggesting origins in North Dakota (Toom, 2004)), the Oneota tradition, and Red River Ware (Taylor, 1994, 1996; Taylor-Hollings, 1999; Voth, 1996), along with a catlinite pipe originating from Minnesota (Taylor, 1996). Although there is no macrobotanical evidence or tools suggesting maize horticulture (Boyd, 2002a; Boyd et al., 2006), phytolith evidence from Boyd et al. (2006) indicates that it was consumed at this site.

Although there is no direct evidence that the Psinomani culture participated in warfare, it is very likely that they did based on fortifications found at the Shea site. However, this is just one site and an unusual one at that (Michlovic and Schneider, 1993). Along with Sandy Lake, Northeastern Plains Village wares and Oneota vessels were also found together at the Shea site (Michlovic and Schneider, 1993).

Johnson (1969c) proposed that Sandy Lake Ware succeeded Blackduck Ware in Northern Minnesota. It has been suggested that the people who made Sandy Lake ware could be ancestral to the Eastern Dakota in central Minnesota and the Assiniboine in southern Canada and sites where both Psinomani and Selkirk components are found represent the material remains of an early Assiniboine or Cree alliance (Taylor-Hollings, 1999).

2.8. A BRIEF OVERVIEW OF THE CULTURES AROUND THE STUDY AREA

This section gives a brief look at the cultures that might have come in contact with the ones examined in this study. The relevance of this is to gain an understanding of the shift towards the use of maize as a staple in the areas south of the study area beginning ~ A.D. 1000.

2.8.1. Plains Woodland Tradition

The Plains Woodland and Plains Village tradition represent different adaptive strategies. Plains Woodland people have been described as being primarily hunters who did some gardening, typically exploited bison (like the other Plains societies), produced ceramic vessels, built storage pits, burial mounds and earthworks that are interpreted as an influence from eastern cultures (Gregg, 1994; Hamilton and Nicholson, 1999, 2005; Johnson and Johnson, 1998).

Plains Woodland sites in southwestern Manitoba are thought to reflect horticultural/foraging based subsistence activities. This is based on the recovery of non-local lithics, stone hoes, milling stones and pottery wares (mostly Sandy Lake type) resembling types found in the Dakotas, Minnesota and Iowa (Boyd, 2002a; Hamilton and Nicholson, 1999, 2005, Nicholson, 1988, 1990, 1991, 1993, 1994, 1996; Nicholson and Hamilton, 1996; Nicholson et al., 2002; Taylor-Hollings, 1999; Schneider, 2002).

Maize and possible storage pits at the Lockport site in southern Manitoba supports the practice of possible maize horticulture on the Canadian Prairies during the late prehistoric period (Boyd, 2002a; Buchner, 1987; Hamilton and Nicholson, 1999, 2005; Nicholson, 1993; Nicholson and Hamilton, 1996). Also, small-scale horticultural production in southern Manitoba has been proposed based upon ethnographic records of "Indian gardens" reported during early European contact in the area, possible bison scapula hoes, site location, and ceramic affinities (Hamilton and Nicholson, 2005). However, so far no other sites on the Canadian Plains have provided unequivocal evidence of local corn production.

2.8.2. Plains Village Tradition

The Plains Village tradition ranges from the eastern plains, from Texas to the Dakotas, and perhaps further northwards into Manitoba, and along the streams and rivers of the Missouri, Mississippi and Red River valleys (Gregg, 1994; Hamilton and Nicholson, 1999). It is an archaeological manifestation dating from A.D. 900 to 1700 and is characterized by semi-permanent villages on river valley terraces with river bottom gardens, village fortifications, rectangular semisubterranean houses, stone and bone hoes, numerous large storage/trash pits, and grit tempered globular jars a blend of Woodland and Mississippian traits (Hamilton and Nicholson, 2005; Lehmer, 1971; Wedel, 1964). Plains Villagers typically subsisted from hunting, foraging, and horticulture (maize, beans and squash) (Gregg, 1994; Hamilton and Nicholson, 2006).

The Plains Village tradition encompasses two early traditions, the Central Plains and Middle Missouri and one later tradition, the Coalescent tradition which is a blend of the other two (Gregg, 1994; Lehmer, 1971). The Mississippian tradition was centred along the Mississippi River and flourished from A.D. 900 to 1300, they made shell tempered pottery, lived in permanent villages, and intensively cultivated maize and other cultigens (Anfinson, 1997). The Middle Missouri tradition is thought to represent the ancestors of the Mandan and Hidatsa (Bowers, 1948; Hewes, 1948; Will and Hecker, 1944).

2.8.3. The Oneota Tradition

In the Prairie Lake Region, another major Late Prehistoric tradition (besides Late Woodland and Plains Village traditions) is the Oneota tradition, a possibly Mississippian-derived society, originally defined in northwestern Iowa (Anfinson, 1997; Boszhardt et al., 1995; Schroeder, 2004).

Mississippian societies are materially different from Late Woodland societies on the basis of pottery tempered with crushed shell, emphasis on agricultural adaptation to riverine settings, and religious ideologies (Schroeder, 2004). Oneota and Fort Ancient are Upper Mississippian societies, or are at least in part derived from Upper Mississippian societies (Schroeder, 2004).

Oneota sites are known to date between A.D. 1000 to the early historic period, they are found as far as the James River Valley of the Dakotas in the west, northern Indiana in the east, central Minnesota in the north, and central Missouri in the south. They are most commonly found in the Prairie Peninsula of Iowa, Illinois, Wisconsin, southern Minnesota, and northern Missouri (Boszhardt et al., 1995). The abandonment of Cambria and Mill Creek Plains Village by A.D. 1300 is thought to be a result of the expansion of the Oneota culture (Gregg, 1994). The Oneota tradition is associated with Siouan speaking peoples on the prairies who practiced agriculture and continued a vigorous tradition of hunting and gathering (Harvey, 1979; Springer and Witkowski, 1982).

Oneota societies had a tribal level of socio-political organization like the Late Woodland societies (Schroeder, 2004). Oneota ceramics are characterized by shell tempered globular ceramics with high, straight rims and plain surfaces with wide-trailed line decorations, and occasionally tempered cord-marked vessels (Schroeder, 2004). Compared to Sandy Lake Ware, Oneota vessels are typically smoothed to burnished; much more elaborately decorated, have a complex profile, and are usually tempered with larger pieces of shell (Cooper and Johnson, 1964; Gibbon, 1995; Ritterbush and Logan, 2000). Non-ceramic artifacts often associated with Oneota include small triangular arrow points, end scrapers, bevelled and unbevelled knives, celts, bifaces, flakes, abraders, grinding slabs, anvils, hammerstones, grooved mauls and bone tools such as scapula hoes, awls, flakers, worked ribs, catlinite pipes, and plaques (Ritterbush and Logan, 2000).

Some evidence points to at least some Oneota people living in rectilinear lodges or elliptical houses (McKusick, 1973) with subterranean bowl shaped storage pits (in eastern Oneota sites) and bell-shaped pits (similar to Plains Village caches) in western Oneota sites (Gibbon, 1995; Michlovic and Schneider, 1993). They were more sedentary than Late Woodland societies at the time, but moved more frequently than people living at large

Mississippian mounds sites further to the south (Schroeder, 2004). The Oneota people would have survived on a dual economy based on maize gardening and bison hunting (Michlovic and Schneider, 1993); however some (Gibbon, 1973; Stoltman, 1986) have suggested that some Oneota groups would have subsisted more heavily from the use of wild plants such as wild rice, and various animals and fish due to the high diversity of resources available, especially in the northern extent of their range. They grew maize, squash, and to lesser extents, various starchy and oily seeds by their villages located on elevated terraces along rivers, lakes, swamps or on elevated soils suited for cultivation with a hoe and digging stick (Stoltman, 1986). The Mississippian people, from which the Oneota are thought to derived from, depended more on horticulture than wild resources, followed settlement patterns based on hierarchy, and lived on alluvial floodplains (Schroeder, 2004).

2.9. ARCHAEOLOGICAL SITES IN THE STUDY AREA

In this section, the information available for selected sites used in this study is discussed (Figure 6). Only limited information is available on certain sites since very little information has been published, where most of the information is available in the form of "grey literature" (government documents, permit reports, etc.). However, the information in the "grey literature" does help in gaining a better understanding of the sites in the study area and helps in developing better interpretations of the data acquired in this study.

2.9.1. The Bundoran Site (DjKn-5)

The Bundoran site is located approximately 20 km south of the town of Kenora, Ontario (Figure 6), and has been interpreted as a multi-component campsite/fishing station occupied in the spring or early summer (Spiedel, 1989). The Bundoran site lies in the southern Rainy River region with a mean annual rainfall of 660.4 mm, a mean daily maximum temperature of 25.5

degrees Celsius (in July), a mean daily minimum temperature of –22.2 degrees Celsius (in January), an average snowfall of 1524 mm, and an average of 104 frost-free days throughout the year (Spiedel, 1989), long enough to grow some varieties of maize.

The Kenora District lies partially within the Boreal Forest region and the transition zone between the Boreal and Great-Lakes-St. Lawrence Forest region. The Bundoran site is located within this transition zone. Wild rice may have existed in the area in prehistoric times since there are modern stands of the plant in the bay near the site today (Spiedel, 1989). Excavations at the Bundoran site were conducted by trowel and earth was sifted through one-quarter inch screen (which would have caused most macrofossils to be lost), and floatation for the recovery of seed remains was not carried out (Spiedel, 1989).

The cultural components that comprised the site were Laurel, Blackduck and Selkirk, as well as a historic ash dump (Spiedel, 1989). The largest feature of the site, a semi-circular alignment of rocks, with associated hearths and artifacts, discovered in the Laurel strata has been interpreted as the remains of a Laurel house structure (Spiedel, 1989, Reid and Rajnovich, 1979) and is similar to other house structures found in prehistoric sites in the Lake of the Woods area. This site was roughly dated by means of ceramic seriation. The Laurel house structure is thought to date to approximately A.D. 900; the Blackduck component is thought to date to A.D. 1200; and the Selkirk component to A.D. 1500 (Spiedel, 1989). Spiedel (1989) suggests that some of the vessels found at the Bundoran site were used for cooking based on the residues in the vessels, and suggests that the Blackduck and Selkirk people might have utilized their vessels more for cooking than the Laurel people since more of them have burned residues on the inside. He does suggest that others were used for storage. Some juvenile pottery (or miniature pots) has also been identified at this site. Spiedel (1989) suggest a late occupation of this site from A.D. 900 and 1200 based on a radiocarbon date and ceramic seriation.

2.9.2. The Spruce Point Site (DjKq-1)

The Spruce Point site is a multi-component site composed of Archaic, Laurel, Blackduck, Selkirk, Sandy Lake, and historic components, and is located on the Southwestern tip of the Northern Peninsula of Lake of the Woods (Figure 6) (Rajnovich, 1983a, 1983b; Reid, 1976; Reid and Rajnovich, 1980; Smith, 1979). The major occupation is Selkirk (Rajnovich, 1983a, 1983b; Reid and Rajnovich, 1980). Evidence of house structures, are also found at this site and are thought to be associated with the Selkirk component at this site (Rajnovich, 1983a, 1983b; Reid and Rajnovich, 1983). The floor size of the houses at the site suggests that they were domed-shaped base on the oval outlines, and that there were multiple or extended family dwellings (Rajnovich, 1983a, 1983b).

The site is thought to have been occupied during the summer or from spring to fall, based on the locations of the houses, and faunal remains (Rajnovich, 1983a). The site is thought to be a summer “home base”, and estimated to have been occupied by about 30 people in “permanent” dwellings adjacent to various resources (Rajnovich, 1983a, 1983b). There is an unusually rich variety of plants at the site and surrounding area compared to other areas around the lake, a high capability for upland game such as moose, and the site is located near a good source of lithic materials (Rajnovich, 1983a). Due to high clay content, soil flotation was unsuccessful in recovering charred seed remains (Rajnovich, 1983a). Animal remains found at this site included beaver, muskrat, squirrel, possible moose, deer/caribou, birds such as the common loon, turtles, and fish such as suckers and lake sturgeon (Rajnovich, 1983a, 1983b).

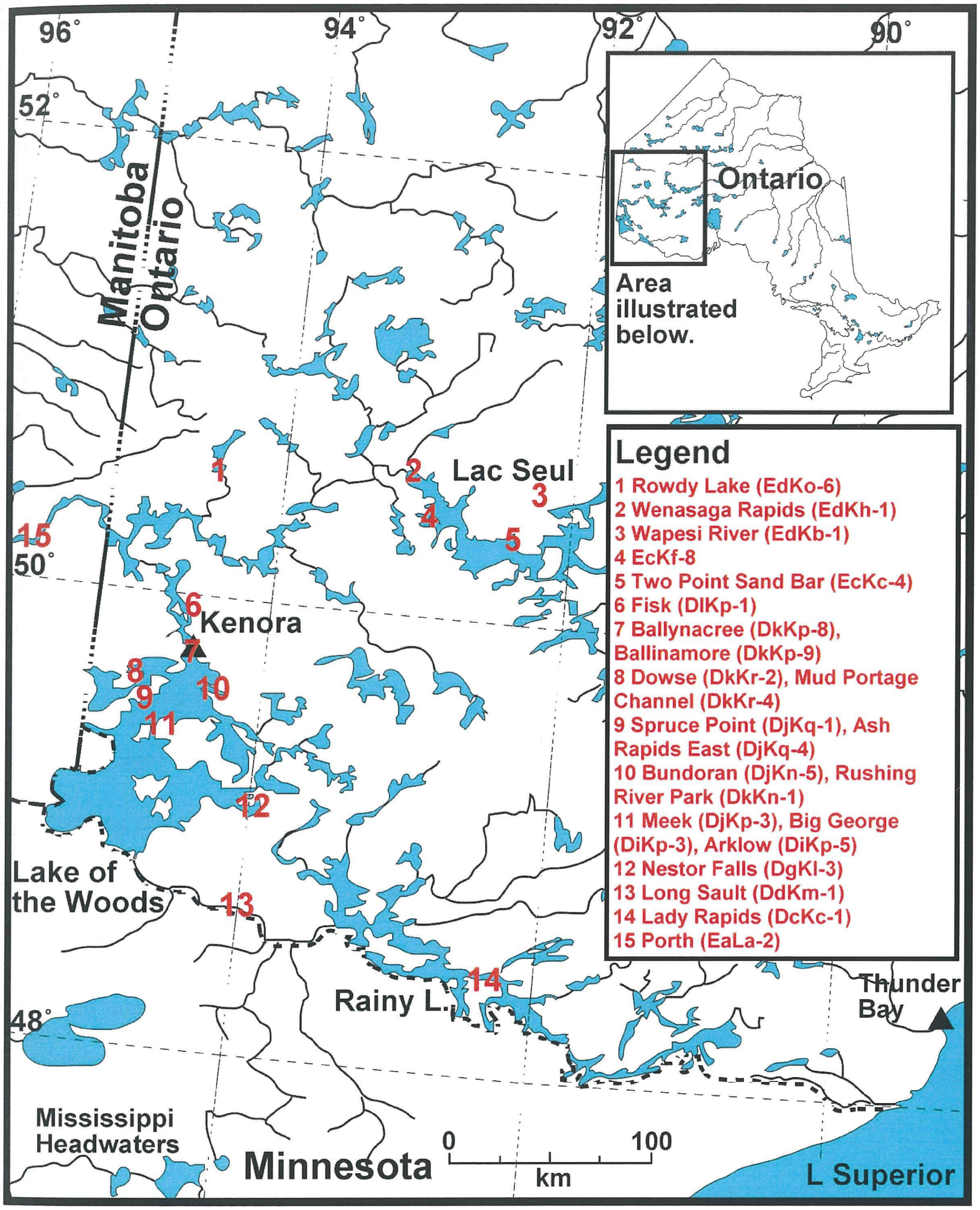

Figure 6. Location of archaeological sites sampled in the Lake of the Woods and surrounding area (base map provided by Scott Hamilton).

2.9.3. The Meek Site (DjKp-3)

The Meek site (DjKp-3) is one of the largest (12140.55 to 20234.25 m^2) prehistoric sites in the Lake of the Woods (Figure 6) (Rajnovich and Reid, 1977, 1978; Reid, 1976). The Meek site (DjKp-3) is a multi-component site composed primarily Selkirk with some Blackduck and Laurel. A single grit-tempered Oneota rim was also included in the assemblage at this site (Reid, 1976). An oval Laurel dwelling was also found at this site (Rajnovich, 1980; Reid and Rajnovich, 1985).

Rajnovich and Reid (1977, 1978) have hypothesized that the site was a major Selkirk village and ceremonial centre, especially with the high productivity of ceramics (25 to 42 rim sherds per one metre excavation unit). Out of 1000 rims recovered, 45% were Selkirk, 15% were Blackduck, 17% were Laurel and 22% remained unclassified, the remaining rims were classified as Clearwater Lake Punctate (Rajnovich and Reid, 1977, 1978).

A major set of petroglyphs are present at the site (Reid, 1976), with the majority representing possible fertility symbols (Rajnovich and Reid, 1977, 1978). A semi-subterranean structure present at the site containing a mass burial has been dated to the Selkirk occupation (Rajnovich and Reid, 1977, 1978). A "Puckasaw" pit and a possible Blackduck burial mound were also uncovered (Reid, 1976). Features at this site include a concentration of semi-fired clay near a hearth and a curved series of rocks and post moulds with a hearth located inside the arc they form (Reid, 1976; Reid and Rajnovich, 1979).

Based on the radiocarbon dates from the Meek site of 930 ± 135 A.D. (uncorrected) and 1410 ± 140 A.D. (uncorrected) and the characterization of some of the Selkirk ceramics as Sturgeon Falls Fabric Impressed and Alexander Fabric Impressed, Rajnovich and Reid (1977, 1978) have estimated an early Selkirk occupation, influenced by contact with Blackduck to a late prehistoric Selkirk occupation. A single Ash Rapids Corded (aka Sandy Lake) was recovered from this site, which is thought to be contemporaneous with the Selkirk occupation of the site

(Reid and Rajnovich, 1980). Dates associated with Laurel ceramics for the Meek site range from A.D. 280, A.D. 390, to A.D. 450, while a date associated with Selkirk ceramics range from A.D. 1350 to 1410 (Spiedel, 1989).

2.9.4. The Fisk Site (DlKp-1)

The Fisk site (DlKp-1) is a small to medium size site (Figure 6), with high quantities of Selkirk (Alexander Fabric Impressed and Surgeon Falls Fabric Impressed) ceramics (Rajnovich and Reid, 1977, 1978). The Fisk site is located at the lower end of the portage from Ena Lake to the MacFarlane River. Cultural materials found indicated the presence of Fur Trade, Selkirk, Blackduck, Laurel (Reid, 1976) and Archaic occupations (Wall, 1980b). Important features encountered at this site included two pits, one of which had heavily burnt bone and ocre, and several post moulds suggesting a house structure, which may be associated with a hearth that was found which are thought to be Laurel in origin (Rajnovich et al., 1982; Reid, 1976; Reid and Rajnovich, 1983). A date of A.D. 50 is associated with Laurel ceramics at this site (Spiedel, 1989).

2.9.5. The Mud Portage Channel Site (DkKr-4)

The Mud Portage Channel site (DkKr-4) is located on a peninsula at the Southwestern extremity of Clearwater Bay, between Woodchuck Bay and Rush Bay (Figure 6). Petroglyphs have also been found near this site. At the Mud Portage Channel site (DkKr-4) eleven one-half meter test pits were excavated along a straight line which paralleled the beach in front of the site where Archaic, Laurel, Blackduck and Selkirk artifacts were found (Wall, 1979). A petroglyph was also associated with this site, and a single Ash Rapids Corded (or Sandy Lake Ware) rim was also identified (Reid and Rajnovich, 1980).

2.9.6. The Ballinacree Site (DkKp-8)

The Ballinacree site (DkKp-8) is located on the south side of a bay at the west tip of Tunnel Island in the Winnipeg River (Figure 6). Laurel, Blackduck, Selkirk and Fur Trade period components were excavated at this site (Reid, 1976). Features encountered included a hearth and a series of post moulds that are thought to date 1000 B.P. (Reid and Rajnovich, 1983). The Ballysadare site (DkKp-10) nearby also revealed some evidence of a house structure (Rajnovich, 1980), and a date of 150 B.C. has been associate with Laurel ceramics at this site (Spiedel, 1989). The site thought to encompass an entire Laurel village with three complete structures and their associated external features (Reid and Rajnovich, 1991). Three pits, as well as a hearth, were found within the outlines of post moulds, one of the pits contained a Laurel rim, the other contained both Laurel and Blackduch sherds, while another was lined with bark, which the investigators thought might have contained seeds (Reid and Rajnovich, 1983).

Dates of A.D. 1240 and A.D. 1270 are associated with Laurel ceramics, and a date of A.D. 1650 is associated with Blackduck ceramics at this site (Spiedel, 1989). Statistical analysis of the ceramics also suggest a late occupation of the site by the Laurel people (Reid and Rajnovich, 1991). Knife River chalcedony from North Dakota, Gunflint Formation silica and jasper taconite from the Thunder Bay-Quetico area, Selkirk chert and Swan chert from Manitoba, and obsidian probably from Wyoming are all good evidence of long distance trade with the people at this site (Reid and Rajnovich, 1991).

2.9.7. The Ballinamore Site (DkKp-9)

The Ballinamore site is located within the boundaries of the Town of Kenora, northwestern Ontario, on the western end of Tunnel Island in the Winnipeg River (Figure 6). The Ballinamore site (DkKp-9) is located directly north of Ballinacree (DkKp-8), and cultural affiliations are similar (Reid, 1976). The site is multicomponent, representing cultures dating from the Archaic Period to the present (Pelleck, 1986). The components include a Pelican Lake phase occupation (Late Archaic period) (Wall, 1980b), a Laurel, Blackduck, Selkirk, and fur trade occupation (Pelleck, 1985, 1986). The site is thought to be primarily a habitation site that might have supported a large population throughout the Woodland Period, a hunting camp during the Archaic Period, and a stopover during the fur trade since it lies along a major water route (Pelleck, 1986). There are abundant floral, faunal, and lithic resources near the site (Pelleck, 1986). Hunting, fishing and woodworking are thought to have been important at this site (Pelleck, 1986). A date of A.D. 490 is associated with Laurel ceramics, and a date of A.D. 940 is associated with Blackduck ceramics at this site (Spiedel, 1989).

2.9.8. The Ash Rapids East Site (DjKq-4)

The Ash Rapids East site (DjKq-4) is located at the entrance to Shoal Lake narrows (Figure 6). It is considered to be a single site with Ash Rapids West (DjKq-5), which is across the rapids (Reid and Rajnovich, 1980). Both are good portages, possess the same cultural affiliations and are suitable areas for fishing camps or villages. This site is multi-component and deeply stratified, containing Plains Archaic, Laurel, Blackduck, Selkirk, and Fur Trade components (Petch, 1984; Reid and Rajnovich, 1980). Ash Rapids Corded (aka Sandy Lake Ware) is a large component at this site (Reid and Rajnovich, 1980). A date of A.D. 1690 is associated with Blackduck or Selkirk ceramics at this site (Petch, 1984; Spiedel, 1989).

2.9.9. The Long Sault Site (DdKm-1)

The Long Sault site (also known as the Armstrong site) is located on the north side of the Rainy River near the Long Sault Rapids (Figure 6) (Rapp Jr. et al., 1995; Wright, 1967). It is associated with eight burial mounds (Wright, 1967), seven of which most likely belong to the Laurel culture while the other was most probably constructed during the Late Woodland period

(Rapp Jr. et al., 1995; Wall, 1980b; Wright, 1967). Laurel is the main component at this site, preceded by a Late Archaic occupation (Rapp Jr. et al., 1995; Wall, 1980b). Laurel ceramics indicate a Late McKinstry phase occupation (Rapp Jr. et al., 1995). Some Blackduck, Selkirk and Sandy Lake components are present in the upper layers at the site (Rapp Jr. et al., 1995). This site is thought to be a village site (Rapp Jr. et al., 1995). Faunal materials and lithics suggest a heavy reliance on fishing at this site for the Laurel people (Rapp Jr. et al., 1995). A radiocarbon date of A.D. 1650 places occupation of the site just prior to the earliest documented European contact in the Rainy River valley (Arthurs, 1986b). Dates ranging from A.D. 500 to 900 are associated with Laurel ceramics, and a date of A.D. 1750 is associated with Selkirk ceramics at this site (Spiedel, 1989).

2.9.10. The Nestor Falls Site (DgKl-3)

The Nestor Falls site, located in the town of Nestor Falls, Ontario (Figure 6), is a small, possibly stratified, multicomponent site positioned on a major transportation route, a portage into Kakabikitchewan Lake (Pastershank, 1989). A major food source is available near the site, as a fish spawning area is present at the base of Nestor Falls (Patershank, 1989). The site contains Laurel, Blackduck, Selkirk and Historic components (Halverson, 1992; Patershank, 1989) and fits the criteria for both a "home base" and "satellite camp" (Halverson, 1992). Cherry, oak and wild plum seeds were found at the site, the oak seeds were the only ones that appeared to have been charred (Halverson, 1992), suggesting that the others were probably intrusive. Some toy or juvenile (or miniature) pottery is also found at this site (Halverson, 1992). Pictographs are also found near this site.

2.9.11. The Lady Rapids Site (DcKc-1)

The Lady Rapids site is located on the Rainy River at Lady Rapids (Figure 6). Laurel and Blackduck components, as well as some post contact remains were found at this site (Callaghan, 1979). Evidence of a dwelling and a burial mound has been found at this site (Callaghan, 1979). A date of A.D. 520 is associated with Laurel ceramics, and a date of A.D. 1480 is associated with Blackduck ceramics at this site (Spiedel, 1989).

2.9.12. Rushing River Park Site (DkKn-1)

The Rushing River Site is located on a point on the north side of the channel where the Rushing River begins (Figure 6) (MacLeod, 1971; Reid, 1975). Components at this site are Selkirk and Historic; however some plain neck and body sherds were also recorded at this site that were not associated with any culture (Reid, 1975). A date of A.D. 1650 is associated with Selkirk ceramics at this site (Reid, 1975; Spiedel, 1989).

2.9.13. Rowdy Lake Portage Site (EdKo-6)

The Rowdy Lake Portage site is located at the outlet of Sydney Lake into Rowdy Lake, near Kenora, Ontario (Figure 6). The site was heavily used, is possibly stratified, and has some bone preservation. Archaeological recoveries found at this site include Laurel, Blackduck, Selkirk, some historic, and perhaps some Archaic components (Hamilton, 2007). There is a high representation of fish remains at this site supported by the importance of the nearby fisheries (Hamilton, 2007). Some sherds seem to exhibit both Selkirk and Blackduck traits.

2.10. SUMMARY

Based on archaeological recoveries, and in particular ceramics, it is often inferred that various groups in the Lake of the Woods area had contact with each other and with groups around them. However, very little work has been done to establish this clearly. It seems probable that the variety of resources in the area and the ease of travel because of the numerous lakes and rivers allowed cultural changes to occur either through displacement, assimilation, warfare (although no evidence supports this), or intermarriage. Exchange networks might be the facilitators in bringing in cultural remains from various places, thus limiting direct interactions to the groups closest to each other.

Based on the observations mentioned above, wild rice (*Zizania* sp.) may be a major factor influencing the cultural development and dispersal of the four major cultures in the study area. However, there is very little, or no evidence of its importance or even of its use at archaeological sites to support these assumptions. This is due to poor preservation, poor recovery techniques, or total lack of archaeobotanical work done in the area (Spiedel, 1989). Maize (*Zea mays*) has been found at sites associated with Blackduck components (Boyd et al., 2006) such as the Lovstrom site in Manitoba and sites associated with Sandy Lake components such as the Duthie site in Manitoba (Boyd et al., 2006) and the Shea site in North Dakota (Michlovic and Schneider, 1993), which leads to the possibility that crops other than wild rice may also have been exploited in the Lake of the Woods.

Laurel populations are thought to have been affected by developments originating in the Ohio, Illinois, and Mississippi River valleys, especially by the Hopewell culture. The recovery of Hopewellian influenced artifacts and burial mounds along the Boundary waters are reflective of this (Hamilton, 2007). Blackduck sites also reflect some southern influence; however the relation between population growth, burial mounds and wild rice is not as clear since they were able to adapt themselves in some areas to an economy primarily based on the hunting of bison (Hamilton et al., 2007).

Several sites in the study area are located near modern wild rice stands, have evidence of house or village structures, burial mounds, and exotic lithics or ceramics. It seems likely that if maize horticulture occurred in northwestern Ontario and heavy exploitation of wild rice, it might be at these sites.

CHAPTER 3. THE DISTRIBUTION, ECOLOGY, AND ANTIQUITY OF WILD RICE (*Zizania* spp.), MAIZE (*Zea mays*), SQUASH (*Cucurbita* sp.), and COMMON BEANS (*Phaseolus vulgaris*)

3.1. INTRODUCTION

This chapter will briefly discuss the nature, distribution and ecology, and antiquity of wild rice (*Zizania* spp.), including maize (*Zea mays*), squash (*Cucurbita* sp.), and common beans (*Phaseolus vulgaris*). This chapter is intended to provide the reader with a brief background on the species of wild rice that exist, the history of its genus, its nutritional value, and factors influencing growth.

3.2. WILD RICE (*Zizania* spp.)

3.2.1. The Plant

Folk names for wild rice include Indian rice, Canadian rice, water rice (Keane, 1997), Indian, water or wild oats and marsh rye (Stickney, 1896). Early French explorers named the plant "folle avoine", which is also the name for wild oats (*Avena fatua*). The use of this French expression was subsequently dropped due to this confusion (Keane, 1997; Wilson, 1956). The Ojibwa called it *Manoomin* meaning, "good berry", while the Cree called it *anoomin* or *athoomin* (Forliti, 2006; Keane, 1997). A sample of wild rice was first collected for description in Virginia by John Clayton in 1739 and sent to J.F. Gronovius in Leyden, Holland, for him to describe in 1743. The scientific name derivation chosen for the genus of wild rice came from the Greek word *zizanion* (a weed of Mediterranean grain fields), and in 1753 Linnaeus provided the binomial nomenclature *Zizania aquatica* for the specimen. Linnaeus chose the plural *zizania* for wild rice adding its Latin species name *aquatica* to distinguish it as a plant that grows in water (Keane, 1997).

Wild rice is classified under the family *Gramineae (Poaceae),* tribe *Oryzoidae* and the genus *Zizania* (Bunzel et al., 2002). Four species of wild rice exist, *Zizania latifolia* or Chinese wild rice, which is native to Asia, and three North American species: *Zizania aquatica*, *Zizania palustris* and *Zizania texana* (Terrell and Wergin, 1981; Zhai et al., 2001; Bunzel et al., 2002). *Zizania aquatica* (Southern wild rice) and *Zizania palustris* (Northern wild rice) are annual species, while the other two species; *Zizania latifolia* (Manchurian water-rice) and *Zizania texana* (Texas wild rice) are perennials (Horne and Kahn, 2000; Keane, 1997).

3.2.2. Distribution, Ecology, and Antiquity

Indigenous to North America, *Zizania* spp. is known to range as far north as Lake Winnipeg to the Gulf of Mexico and eastward from the Rocky Mountains to the Atlantic Coast (Figure 7) (Keane, 1997; Lorenz, 1981). The prehistoric range of wild rice and the age of natural stands in lakes are not well understood (McAndrews, 1969), and therefore it is not well known where and when people first started to exploit this resource. Today, *Zizania aquatica* and *Zizania palustris* overlap with each other in some areas (Figure 7). *Zizania texana* is also indigenous to North America; however it only grows in Texas today (Keane, 1997). *Zizania latifolia* grows in the lakes of China; it is smaller and lighter in colour (green or brown) than North American wild rice (Zhai et al., 2001).

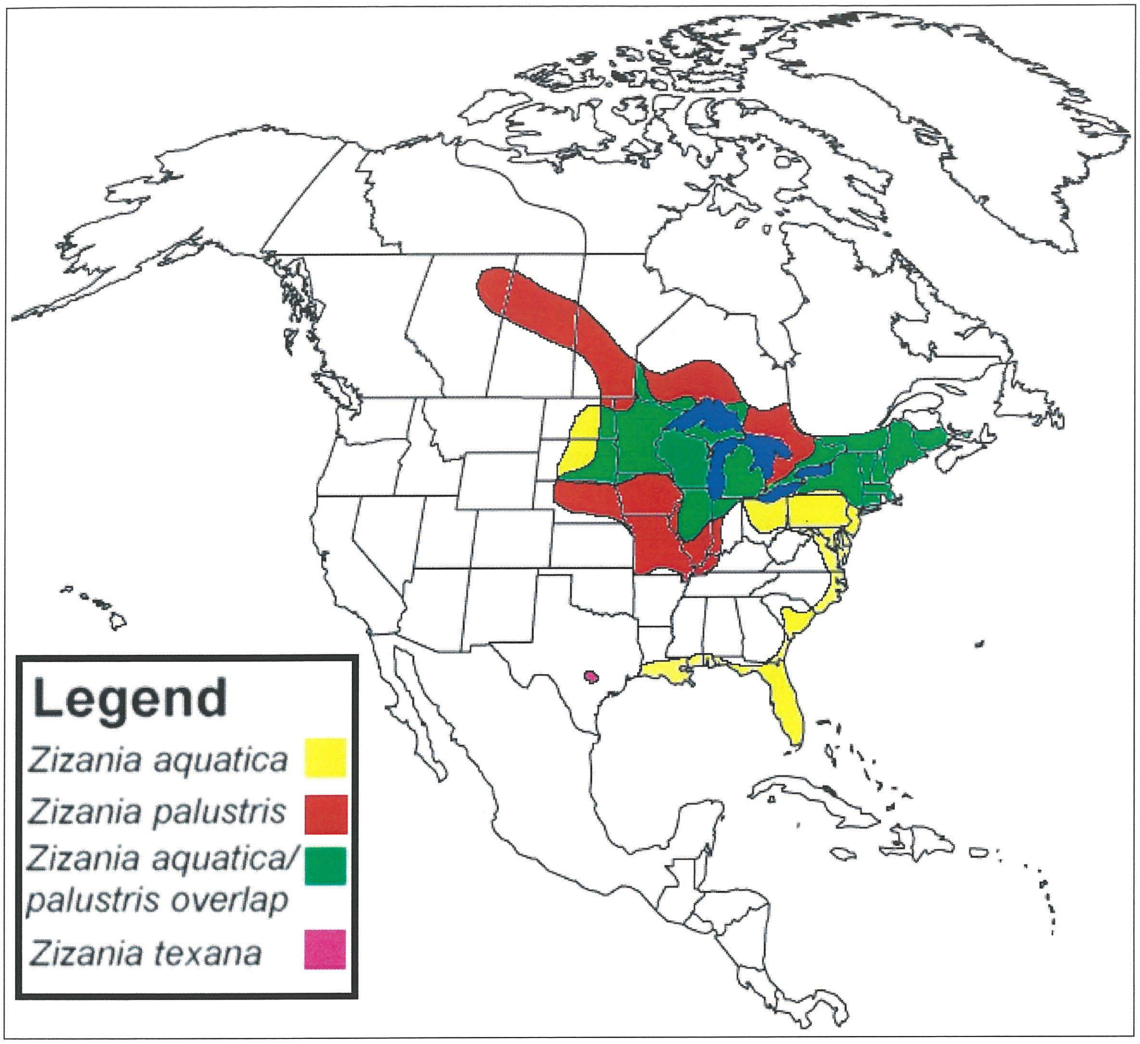

Figure 7. Modern distribution of wild rice (*Zizania* spp.) in North America (after Archibold et al., 1985; Barkworth, 2007).

Zizania aquatica (southern wild rice) and *Zizania palustris* (northern wild rice) are annual aquatic grasses growing in extensive stands in shallow lakes and slow-flowing streams of the Great Lakes region (Archibold et al., 1985; Drewes and Silbernagel, 2004; Keane, 1997; Kuhnlein and Turner, 1991; Stickney, 1896; Quayyum et al., 1999). These species often occupy small bays of large lakes, the mud flats on tidal rivers (for *Zizania aquatica* var. *brevis* only), and are rarely found in inland lakes with no outlets (Keane, 1997). These species grow well in rich, muddy, slimy bottoms on a variety of soils under fresh-water streams and marshy lakes (Stickney, 1896; Keane, 1997), but they can be sensitive to temperature and pollution (Vogel, 1990). A layer of 15-45 cm of loose silts or clays and organic materials provides optimal growing conditions since it permits full root growth and anchorage for the wild rice (Archibold et al., 1985).

Wild rice does not usually appear on the surface of the water before mid-June and at maturity the stems can rise two metres or more above the water line (Duvall and Biesboer, 1988; Kuhnlein and Turner, 1991). Flowers are usually present by early August in loosely branched clusters at the top of the stem, the female, seed-producing flowers are found on the stiff upper branches while the male or pollen bearing flowers are found on the lower, more flexible spreading branches (Kuhnlein and Turner, 1991). The grains usually turn brown at maturity, at which the hulls with the enclosed grains “shatter” or drop off in the water (Kuhnlein and Turner, 1991; Vennum, 1988).

Zizania palustris is differentiated from *Zizania aquatica* by the following characteristics: it is 0.5 to 3.0 m in height; the hull of the grain is firm and leathery (Duvall and Biesboer, 1988), skinny and smooth on the surface with scabrous prickles along the veins. *Zizania palustris* is divided into two subtypes var. *palustris* and var. *interior*. In many works *Zizania palustris* is often referred to as *Zizania aquatica*; however, it is now known that they are two different species.

Zizania aquatica is characterized by the following: it is 0.25-3.0 m in height; the hull of the grain is thin, papery, dull, and minutely roughened on the surface (Duvall and Biesboer, 1988); and the aborted spikelets shrink and become thread-like, less than 1 mm thick (Keane, 1997). *Z. aquatica* has 4 to 6 leaves, which are up to 5 cm in width and up to 65 cm long; it is naturally a freshwater plant but does grow near the mouth of tidewater rivers in salt concentration up to 0.17% (Lorenz, 1981).

Zizania aquatica is divided into two subtypes: var. *aquatica* and var. *brevis*. *Zizania aquatica* var. *brevis* (estuarine wild rice) has been documented in the extensive non-saline tidal flats of the St. Lawrence River from Grondines, in the west, almost continuously to Trois-Saumons in the east (Darbyshire and Aiken, 1986). *Zizania aquatica* var. *aquatica* ranges closely to that of var. *brevis* from the southwest in the upper St. Lawrence River and the Richelieu River, well beyond any tidal flat influences (Darbyshire and Aiken, 1986). *Zizania palustris* also occurs in the St. Lawrence River at least as far east as Quebec City in non-tidal sites (Figure 7). Differences between *Zizania aquatica* var. *brevis* and other *Zizania* taxa are caused by its adaptation to its unique habitat and isolation (Darbyshire and Aiken, 1986).

The length and the character of the growing season are the main climatic considerations for the growth of wild rice. Germination of wild rice occurs between a temperature of 4 and 6°C when the spring overturn in lakes and spring flood in streams ameliorates oxygen conditions. The life cycle of *Zizania palustris* is about 110 days, where approximately 1,500 growing degree-days from a base temperature of 5°C is required for maturity (Archibold et al., 1985). The northern limits of wild rice appear to be limited by heat requirements and length of the frost-free period. Since *Zizania aquatica* lives in shallower littoral habitats, it normally matures faster than the northern varieties (*Zizania palustris*) (Archibold et al., 1985).

Competition for light (shading during early stages of growth by floating plants, i.e., pond lilies), nutrients and space can have potential effects on wild rice growth (Archibold et al., 1985; Lee, 1987; Quayyum, 1995). Other major factors that seem to affect wild rice growth are climate changes, water depth (Macins, 1969), and flowing water (Quayyum, 1995). Stagnant water of swamps, still water of small spring lakes (Archibold et al., 1985; Stickney, 1896), and high sulphate waters (50 parts per million) do not allow wild rice growth (Moyle, 1944). The latter is thought to be the reasons why lakes carrying wild rice aren't found outside of the pine-hardwood forests where they thrive the best (Moyle, 1944).

Some species of wild rice such as interior wild rice grow best at depths of 0.6 m or less, while northern wild rice is better adapted to deeper water at depths of 0.5 to 1.0 m, and a rise of

15 cm during the floating leaf stage might reduce vigour while a rise of 30 cm will drown the plant (Archibold et al., 1985). High water levels due to high precipitation in the form of snow or rain will result in slowing the development of the plant and cause a reduction in seed production, thus possibly causing crop failure for the year (Macins, 1969). The detrimental affects on wild rice occur most often when water levels are either too low or too high during the submersed and floating leaf stages, when the plant is most susceptible to mechanical damage by wind and wave action (Archibold et al., 1985; Thomas and Stewart, 1969).

Some (Finkelstein et al., 2005; Fitzpatrick et al., 2003; McAndrews, 1969; Lee et al., 2004) have used pollen from sediment cores in order to answer when the first appearance of northern wild rice occurred, when people began to consume it (based on possible connections to archaeological sites) and its Holocene distribution. McAndrews (1969) measured 100 comparative wild rice pollen grains and found that 96 of these pollen grains ranged in diameter from 25-32 μm, which tended to be larger than those produced in other wild grasses. In lake sediments, he also found that wild rice seeds were only present in zones where grass pollen exceeded 80%.

As part of the reconstruction of the ecological history of the area in a study by Fitzpatrick et al.'s (2003), wild rice pollen from Musky Bay, Lac Courte Oreilles, Wisconsin and Irving Lake, Wisconsin was compared. Based on their results, the size range of the pollen was 27-33 μm in diameter with a psilate (smooth) texture on the pollen grain surface (Figure 8). Other grass pollen was also recovered which were not believed to be from wild rice since they did not have a smooth surface texture, but a wart-like (verrucate) texture and a smaller diameter (about 20-22 μm) (Fitzpatrick et al., 2003). The mean diameter for the pollen grain was between 28.5 μm (Musky Bay) and 29.2 μm (Irving Lake), with a mean length between 29.8 μm (Irving Lake) and 31.6 μm (Musky Bay), and in both lakes the grains had protruding annulate pores with a width of 8-9 μm and a height of 2.5 μm (Fitzpatrick et al., 2003).

As described above, wild rice pollen in sediments tends to be identified based on size and texture because the pollen grains tend to be bigger than other grasses in or around aquatic settings (Finkelstein et al., 2005; Fitzpatrick et al., 2003; McAndrews, 1969); however some grass pollen such as *Glyceria canadensis* and *Phalaris arundinacea* have been noted to overlap with wild rice pollen (Lee et al., 2004).

To remedy this, Lee et al. (2004) looked at the micromorphology (based on size and sculpturing) of wild rice (*Zizania aquatica*) pollen grains with the use of the Scanning Electron Microscope in order to differentiate them from other grass pollen in the cores from Cootes Paradise, Ontario. They found that fossil pollen from a core at Bull's Point (where wild rice pollen was expected based on its modern presence) revealed pollen grains that were similar in size to those of mannagrass (*Glyceria Canadensis*), not wild rice (Lee et al., 2004). With the use of Scanning Electron microscopy, smaller grains (smaller than the expected range described above) of wild rice (*Zizania aquatica*) pollen were identified and differentiated from other grasses in the same core. Their identification was based on surface morphology consisting of both isolated spinulae and a large widely spaced insulae (each with the densest sculpturing on its annulus, the collar around the single pore) (Lee et al. 2004). Lee et al. (2004) concluded that the fossil pollen from the Bull's Point core was *Zizania aquatica* based on its sculpturing. They explained that the smaller sizes of the pollen grains, seen at this location, were due to site variability. They also add that since wild rice is naturally found in patchy, peripheral and isolated populations, and can self-pollinate, it may display genetic variations (Lee et al., 2004).

McAndrews (1969) determined that the initial increase of wild rice pollen in Rice Lake, Becker County, Minnesota, began approximately 2450 ± 100 B.P. to 1935 ± 100 B.P. According to their research, Lee et al. (2004) argued that the pollen spectra recovered in cores from Cootes Paradise Ontario, indicates at least a 3000 year history of dense wild rice stands; however this does not necessarily mean that people were exploiting them, or that this represents the first regional appearance of the plant. Finkelstein et al.'s (2005) study at Cootes Paradise, Ontario revealed similar data to the study done by Lee et al. (2004), where they argue that around 2100 radiocarbon years B.P., there was a decline of epiphytic diatoms (*Epithemia* spp.) and a rise of Poaceae (cf. *Zizania aquatica*) pollen as well as an increase in pollen concentration suggesting a water level rise. From the evidence provided by the pollen records in Minnesota, Huber (2000) suggests that wild rice was probably present in harvestable quantities at various times as early as 9,000 years ago. However, this idea goes against McAndrews' (1969) evidence of a late Holocene appearance of wild rice in Minnesota.

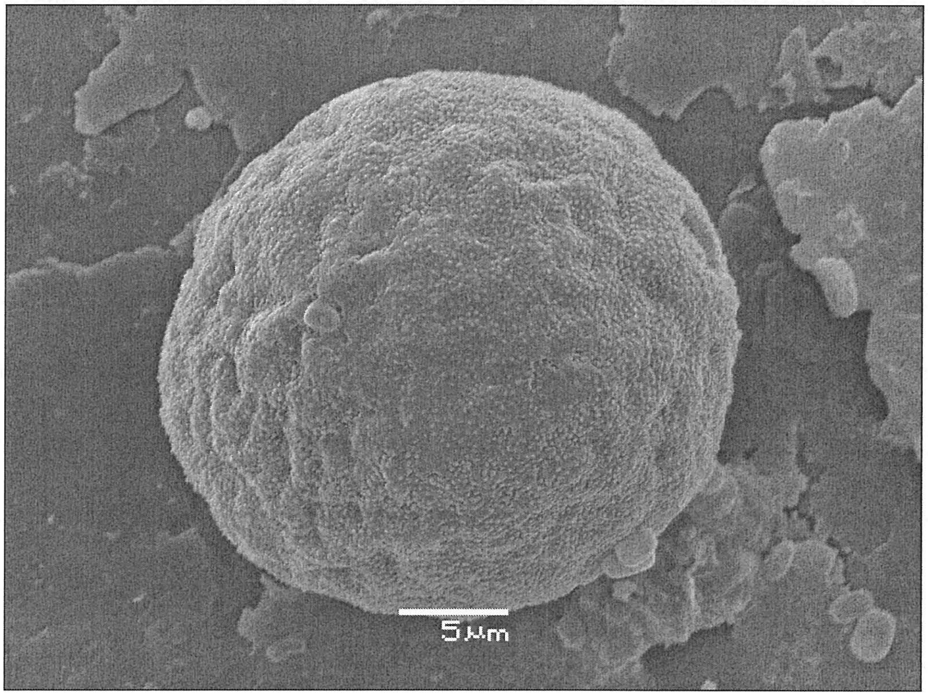

Figure 8. SEM image of Northern wild rice (*Zizania palustris*) pollen.

3.2.3. Nutritional Value of Wild Rice (*Zizania* spp.)

In recent years wild rice has received increased attention as a human food crop. However, it is difficult to predict crop yield from year to year since it has many undesirable characteristics, making it unsuitable for production with standard agronomic practices (Foster and Rutger, 1980). In a study by Zhai et al. (2001), North American wild rice (*Zizania* *aquatica/palustris*) samples obtained from Shoal Lake, Ontario and from another source in Minnesota, were found to have comparable nutritional value to Chinese wild rice (*Zizania latifolia*) (Zhai et al., 2001).

Wild rice (*Zizania aquatica*) is very nutritious, which according to Bunzel et al. (2002), because of its processing, creates a pleasant, nutty taste that distinguishes it from other cereals. It is high in protein, carbohydrates, and minerals but low in fats, it is also rich in vitamin B complex, particularly riboflavin, and is comparable to other cereals in terms of nutritional quality (Bunzel et al., 2002; Keane, 1997; Lorenz, 1981; Vennum, 1988; Zhai et al., 2002). Its fat content is less than 1% and it has up to 38% of linolenic and linoleic fatty acids (Keane, 1997). The carbohydrate content in wild rice (*Zizania aquatica*) totals about 75 %, of which 60 to 65 % is starch, 1.7 to 2.9 % are pentosans, 0.65 to 1.94 % is crude fibre, and 1.10 to 3.70 % is sugar (Lorenz, 1981).

The amylose starch content of wild rice (*Zizania* sp.) is very low (about 2 %) compared to regular white rice (*Oryza* sp.) (Lorenz, 1981). The starch granules of wild rice (*Zizania aquatica*) are embedded in a protein matrix within the endosperm, are smaller in size (2 to 7 μ) than granules of wheat starch or any other common cereal starches, and produce an A-type pattern on X-ray diffraction (Lorenz, 1981). Gelatinization (the temperature at which starch grains lose their birefringence) of wild rice (*Z. aquatica*) starch is higher than that of wheat starch, but similar to that of regular white rice (Lorenz, 1981).

3.3. MAIZE (*Zea mays*)

3.3.1. The Plant

Maize or Indian corn (*Zea mays spp. mays*) is a herbaceous annual growing up to three metres or more. Male and female flowers are carried in different parts of the plant; the pollen producing male flowers are in the terminal tassels at the top of the plant, while the female flower spikes or ears are enclosed in the many layers of the leafy husk producing long silky style strings (Kuhnlein and Turner, 1991). The grains remain attached in crowded rows on the central cob within the husk (Kuhnlein and Turner, 1991).

3.3.2. Distribution, Ecology and Antiquity

The earliest evidence of maize from Mexico dates back to approximately 5000 B.C. (Pope et al., 2001), it is most likely related to Teosinte (*Zea mays spp. mexicana*), a closely related grass that grows in west-central Mexico (Cutler and Blake, 2001). Cultivated maize is thought to have originated in southern Mexico and Guatemala (Kuhnlein and Turner, 1991). It occurs in Canada only under cultivation but can be found on roadsides or waste places (Kuhnlein and Turner, 1991). Before the arrival of Europeans, maize was distributed throughout much of the two continents ranging from the Northern Plains, to the Eastern woodlands of North America to the tropical forests of Central and South America (Figure 9) (Pearsall et al., 2004b). Maize is among the most adaptive of all domesticated plants; it is able to survive in many locations and under a variety of climatic conditions.

Aboriginal varieties of maize from the Plains to the New York region included white, yellow, and blue corn, flour and flint variants, and occasionally sweet corn (Cutler and Blake, 2001). Varieties in the Dakotas were small-grained, while the ones in New York and New England were big-grained (Carter, 1946). The presence of sweet corn among Native Americans is described by Carter (1948): the Iroquois and the tribes of the Upper Missouri River such as the Mandan, the Hidatsa, the Cheyenne, the Omaha, the Pawnee, and the Ponka, among many others, are thought to have had sweet corn during pre-Columbian times.

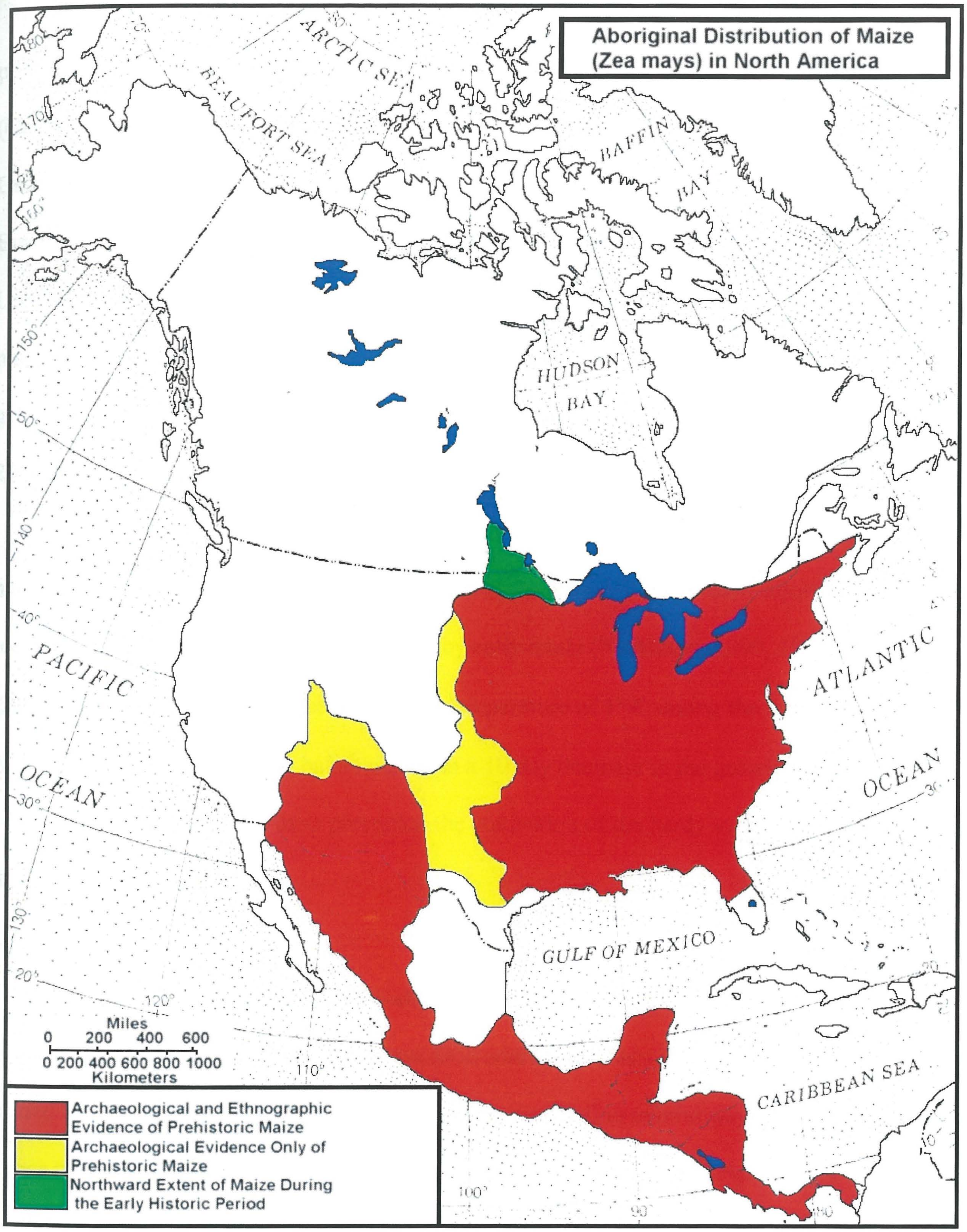

Figure 9. Prehistoric and historic distribution of maize (*Zea mays*) in North America (modified from Moodie and Kaye, 1969).

Eastern Eight Row, also known as Northern Flint, was one of the main varieties that people ate on the Northern Plains and as far north and east as southern Ontario before A.D. 800 (Cutler and Blake, 2001). Historically, northern flint was cultivated in southern Canada, the Gaspé Peninsula, and St. Lawrence Valley by the Hurons and the Iroquois when the first Europeans arrived (Kuhnlein and Turner, 1991). Flint corn was also grown along the Canada-United States border in the past (Carter, 1946). Northern Flint matures early and is cold resistant, the hard starch makes the ears resistant to rot and insects, and it has been known to grow as far north as North Dakota and the lower St. Lawrence River Valley (Cutler and Blake, 2001; Schneider, 2002).

Some Aboriginal varieties of corn such as flint grown by Mississippian populations often matured in 90 days, and other varieties were known to grow within 60 days, allowing them to reach maturity before they could be affected by early frosts (Nicholson, 1990, 1991). Schneider (2002) suggests that the decrease in growing temperature of 1° C during the Little Ice Age (ca. A.D. 1550-1883) which might have resulted in a 10 day decrease in the growing season (from 140 to 130 days) would not have prevented the cultivation of the hardy varieties of short season flint maize.

3.3.3. The Nutritional and Cultural Value of Maize (*Zea mays*)

Maize (*Zea mays*) was an important food source; as it was easily produced, stored and carried over long distances. Maize (*Zea mays*) was prepared in several ways by the Chippewa. Either they roasted the ears in the husk, cut the maize before it was fully ripe, shelled it, dried it, or boiled and seasoned it with maple sugar. Once the corn was harvested from the field, Plains Villagers often left them hanging to dry from their husks and then stored the maize in large underground pits (often with the kernels still on the cobs) (Cutler and Blake, 2001; Wilson, 1987).

It could also be parched, pounded with a stone and added in a soup, boiled in "hominy" (a weak lye made from hardwood ashes) then rinsed, and boiled in clear water (Densmore, 1974). The addition of hardwood ashes has been shown to be an important part of aboriginal diets, since it increases the nutritional quality of maize by increasing the ratio of essential amino acids (Blake, 2001). Therefore, avoiding any dietary deficiencies of an exclusive diet of corn not processed with hardwood ashes, since the exclusive consumption of maize can lead to the development of diseases such as pellagra (Cutler and Blake, 2001). Maize processed in this manner was also made into cakes to be taken on long journeys (Cutler and Blake, 2001; Wilson, 1987).

Toasted or parched corn was prepared by the Indians of the Plains and by the Iroquois (Cutler and Blake, 2001; Wilson, 1987). Two types of parched food were prepared that were also popular in Mexico: one type of parched corn, called pinole, was prepared by toasting the grains and grounding them, and flavoured with leaves; the other called esquiate was prepared by toasting the grains, which were mashed with water and flavoring and prepared into a paste (Cutler and Blake, 2001). The maize can also be treated by boiling it when ripe, pounded and then sifted, making a high energy food with very little weight (Blake, 2001).

Maize, as well as other produce such as squash are represented in Mississipian and Caddoan iconography, due to their importance as a sign of fertility (Schroeder, 1999). Early historic records of societies in southeastern North America suggest that maize was regarded as a valuable commodity offered to highly ranked people as a gift or as a tribute (Bourne, 1904).

3.4. SQUASH (*Cucurbita* sp.) AND COMMON BEANS (*Phaseolus vulgaris*)

Squash, Pumpkins and Melons (*Cucurbita* spp.) are other important Indigenous cultivars that was apparently once confined to the Great Lakes region of Canada, now widely distributed (Kuhnlein and Turner, 1991). Squash and gourds were among the earliest plants domesticated in the Americas (Piperno et al., 2000). Wild *Cucurbita* are thought to have been naturalized in northeastern North America around 4000 to 5000 years ago, with domestic squash grown in the area around 3000 years ago (Monaghan et al., 2006).

There are five species of cultivated *Cucurbita,* of which only three are cultivated in North America: *Cucurbita pepo* (includes pumpkin, acorn squash, zucchini, etc.), *Cucurbita moschata,* and *Cucurbita argyrosperma* (Perkl, 1998). The period required for *Cucurbita* to grow is 120-140 warm, frost-free days (Perkl, 1998). They require well drained soils, and prefer disturbed areas such as garden plots or trash heaps (King, 1985). Based on their observations on the modern-day distributions of free-living *Cucurbita* varieties located south of the Great Lakes, Monaghan et al. (2006) argue that this demonstrates the ability of these plants to naturalize in northern, and relatively harsh climates.

Besides maize (*Zea mays*), the historical Ojibway have been known to have made use of pumpkins and squashes that they would have cultivated in gardens (Densmore, 1974). Like corn and beans, squashes were viewed as being spiritually important for aboriginal groups such as the Iroquois (Kuhnlein and Turner, 1991). Squashes were often the main food during some seasons but were also dried and stored (Kuhnlein and Turner, 1991). The Iroquois are known to have boiled, bake them in ashes, fried them, eaten them whole, mixed with meat or maple sugar, dried in slices, made into a sauce or pudding, and cooked them with green beans (Kuhnlein and Turner, 1991). It is possible that the Ojibwa, Huron, and Potawatomi also had squash and pumpkins before European contact (Kuhnlein and Turner, 1991).

Beans (*Phaseolus vulgaris*) come in various sizes and colours, as do their seeds (Kuhnlein and Turner, 1991). They are widely used today, from their origins in South America, they spread as cultivated food through Central America, as well as southern and eastern North America long before the arrival of Europeans (Kuhnlein and Turner, 1991). Beans were important economically and spiritually for many Indigenous groups such as the Iroquois

(Kuhnlein and Turner, 1991). The Ojibwa, Huron, Potawatomi and other native groups also cultivated beans historically and perhaps before European arrival (Kuhnlein and Turner, 1991). Beans were eaten green or in the pod, cooked and eaten whole, or boiled with squash, corn or meat (Kuhnlein and Turner, 1991). However, beans were commonly left to ripen, were shelled, and the seeds were cooked or eaten whole, mashed, or mixed with corn bread paste, and used for trade (Kuhnlein and Turner, 1991).

3.5. SUMMARY

The origins of prehistoric wild rice populations is unknown; however work by Finkelstein et al. (2005), McAndrews (1969), and Lee et al. (2004) suggest that wild rice populations were in the Great Lakes region from at least 2000 – 3000 B.P. Wild rice is very nutritious and would have been an excellent food source for prehistoric populations. Competition for light, nutrients, space, climate change, flowing water, and water depths have potential effects on the production and growth of wild rice can have potential effects on wild rice growth (Archibold et al., 1985; Lee, 1987; Quayyum, 1995).

Since wild rice cannot always be identified based on size alone, the technique used to identify fossil wild rice pollen in lake cores by Lee et al. (2004) seems like a good approach, but they also note how time consuming it is to identify wild rice pollen on the Scanning Electron Microscope and how this equipment might not be readily available to everyone. They find that the traditional approaches of identifying wild rice pollen are still both very easy and useful for wetland community reconstruction and for local paleoenvironmental reconstruction since it can often be identified through size differences or due to huge contribution of Poaceae (Lee et al., 2004) pollen in the sediment. High concentrations of Poaceae pollen usually implies production by a local grass growing in dense, monospecific stands, which is usually wild rice. However, because the size of wild rice pollen can vary, it is important to have alternative techniques such as the Scanning Electron Microscope or phytoliths to properly identify the plant.

The potential of horticulture by Aboriginal societies in the study area, under the right conditions (soil quality, maximum solar capture, etc.), may have been possible since some varieties of maize such as flint which mature between 60 to 90 days were used by some Native People during the prehistoric period (Nicholson, 1990, 1991; Schneider, 2002) and where the frost free period in the area is 120 to 128 days (Meyer and Hamilton, 1994; Zoltai, 1965). Maize (*Zea mays*) would have been an important food source in the area since it can be easily produced, stored and carried over long distances.

Based on the frost free period in the study area (Meyer and Hamilton, 1994; Zoltai, 1965), and the growth period required for squashes (*Cucurbits*) it is also possible that people might have cultivated them during prehistoric times, assuming soil conditions were met. Based on its late entry into North America, it is likely that beans (*Phaseolus* sp.) made their appearance very late, if at all, in the study area.

CHAPTER 4: ETHNOHISTORICAL AND ARCHAEOLOGICAL EVIDENCE OF WILD AND CULTIVATED PLANTS

4.1. INTRODUCTION

In order to better understand the role of wild and cultivated plants in human history, this chapter will discuss the documented ethnohistorical and archaeological evidence on wild and cultivated plants, especially wild rice (*Zizania* sp.) and maize (*Zea mays*). The purpose of this chapter will be to outline the distribution of the prehistoric use of both wild rice (*Zizania* sp.) and maize (*Zea mays*); as well as pointing out what kind of evidence recovered. The ethnohistorical aspect of this chapter is to help with the interpretations of the archaeological evidence presented both in this thesis and from other sources.

4.2. ETHNOHISTORICAL AND ARCHAEOLOGICAL EVIDENCE OF WILD RICE (*Zizania* sp.)

4.2.1 Ethnohistorical Evidence of Wild Rice

Even today, wild rice is an important commodity for the Ojibwa. In Minnesota ricing is an important tradition, at the White Earth Indian Reservation for example, where unemployement is nearly 50 percent, ricing is a means of survival (Wilcox, 2007). The Ojibwa of the White Earth Indian reserve harvest more than 50,000 pounds of wild rice every autumn (Wilcox, 2007).

Northern wild rice (*Z. palustris var. palustris*) has become an important crop in North America; it is patchily distributed from the Maritime Provinces and northern New England through the Upper Great Lakes and across the Prairies (Lee et al., 2004) (Figure 7). Today, most of the wild rice that is harvested commercially in paddies comes from Minnesota, with smaller amounts produced in Canada and Wisconsin (Lorenz, 1981). For example, wild rice is grown for paddy production on approximately 6,882 ha in Minnesota, contributing over $41.6 million to the State's economy every year (Nyvall et al., 1999). Research on the transformation of wild rice into a domestic crop (Kennard et al., 1999, 2002), and wild rice management (Lu et al., 2005) issues have received much attention in recent years.

With the advent of mechanization and the movement to paddy production by Euro-Americans in the mid-1900s, Native People (especially the Ojibwa) have lost most control over this natural resource (Keane, 1973; Vennum, 1988; Drewes and Silbernagel, 2004). Many decisions made by both Canadian and American governments in the dealings of wild rice have been put into question, among these include the suggestion of wild rice harvesting licenses becoming available to all provincial citizens and the potential yield of wild rice in order to transform it into a cash crop (Rajnovich, 1984). This creates serious issues, since the position held by Native People is that they have a claim to harvesting wild rice because of long standing-tradition in the area. Over the years people such as Johnson (1969a) and Rajnovich (1984) have tried to clarify the issue by providing information on just how long Natives have been ricing in the Lake of the Woods and surrounding areas.

Historically, wild rice (*Zizania* sp.) was an important staple crop to some native groups such as the Ojibway and the Cree, as well as an important means of subsistence for fur traders, primarily in the area between the Great Lakes and the prairie (Lithman, 1973). Besides being an important food source, wild rice provided a shelter for hunting wildlife (Drewes and Silbernagel, 2004). The earliest written records of wild rice in the Lake of the Woods area include an account by LaVerendrye in 1732 to the Marquis of Beauharnois, Governor General of New France (LaVerendrye, 1968). He recorded the failure of the wild rice crops in 1733 due to heavy rains and their plentiful return in 1736, when the Cree presented him with ten or twelve bags (LaVerendrye, 1968).

Wild rice has been described as a spontaneous crop that does not require plowing or sowing, no care while coming to maturity, and provides an abundant harvest of palatable and nourishing grain every year (Lorenz, 1981; Stickney, 1896). Due to varying conditions there might not always be an ample crop every year, since the plant is difficult to domesticate (Vogel, 1990). However, because it can be found in various lakes, crop failure of wild rice is less of an issue than a crop failure with other plants such as corn, since it is not likely that no wild rice can be found even in a bad year (Stickney, 1896; Lofstrom, 1987). This is perhaps, in part, why some early Europeans explorers mention that some native groups (Ojibwa) revered wild rice as one of their most important staple for subsistence, far more important to them than corn (Stickney, 1896).

Native People incorporated wild rice into the cycle of Wenabozhoo (Venibozho) stories, which are deeply held religious beliefs, ceremonies, ethical and social codes of conduct and explanations of natural phenomena (Keane, 1997). Wild rice camps were often set up near rice beds in August where festive occasions took place such as dances, games, and ceremonies that accompanied or followed these gatherings (Vogel, 1990). Harvesting of wild rice marked an important time in the year and preceded the great annual autumnal hunt (Stickney, 1896). Besides appearing in a number of legends, wild rice was used internally and externally in medicine (Vogel, 1990). Maize was the only other plant to hold an equal importance to *manomin* (wild rice) as a native food in North America (Vogel, 1990).

Traditionally wild rice was harvested from a canoe, where one person paddles, and the other harvests. The Ojibwa called August "Manominikegisiss" or "rice-making moon", during the beginning of the month they would prepare large quantities of cedar-bark rope or twine which was rolled into large balls for convenience in handling (Stickney, 1896). In the middle of August (perhaps later in some northern areas) when the rice was still in milk (when the grain is still immature), two women per canoe would visit the rice fields, one paddling or pushing the canoe and the other would gather as many stalks as she could and would fasten them together in a sheaf by passing her twine around the stalks just below the heads and tying it (Densmore, 1974;

Stickney, 1896). This would enable the women to gather the harvest (around the end of August) with less trouble by being able to handle the sheaf more easily and more securely, avoiding less grains to be knocked into the water during handling and strong winds (Stickney, 1896). Stalks were not always tied together with twine; some women would gather a handful of stalks and twist them together downward so they could ripen.

When it was time to harvest, each woman would know which stalks were hers by the type of twist, therefore ownership was respected (Stickney, 1896). The harvesting could be done by hand or with the use two specialized cedar sticks, these sticks are three feet in length, are $1^{1/4}$ inch in diameter at the butt and taper almost to a point, one of them is often made with a curved hook at one end (Stickney, 1896). The rice was bent into the canoe with the curved stick and the seeds were knocked into the canoe by striking the heads with the other stick (Densmore, 1974; Keane, 1997; Stickney, 1896; Vogel, 1990). Not all grains were harvested since some grains had to be left on the stalk for natural reseeding (Densmore, 1974; Vogel, 1990). When one end of the canoe was full, the women would exchange implements and duties, keeping their respective seats, until the other end of the canoe was also loaded, then the women would push the canoe to the shore to begin their preparation for drying and separating of the rice (Stickney, 1896).

Wild rice grains underwent drying, parching or scorching, hulling and winnowing, and if protected from insect and moisture the grains could be stored almost indefinitely (Vogel, 1990). Stickney (1896) explains three ways the grain was traditionally dried by the Ojibwa: it could merely be spread on birch bark, skins or blankets in the sun until it was thoroughly cured; it could be parched a handful at a time in a kettle over the fire, this was usually the quickest way of drying the rice, except that this method destroys to some extent the nutritive qualities of the grain; another method to dry the rice was to place a mat of basswood or cedar bark, upon which the rice was held, on top of a light scaffold called "abwadjigan" about three feet from the ground with a slow fire underneath. The scaffold was sometimes enclosed by a hedge or fence of green cedar branches to confine the heat and hasten the drying process; the rice on the mat was shaken from time to time, drying the grains in about a day (Stickney, 1896). Besides loosening the husk, the parching also imparted a flavour to the rice (Densmore, 1974). Another method in preparing wild rice is known as 'hard rice', where the grains are greenish black in colour, usually much darker than parched rice, requiring longer to cook, can be kept almost indefinitely, and could be used for seed (Densmore, 1974). To achieve this, the rice was prepared on a frame where berries would be dried, where it was covered in a layer of hay to a depth of about 3 inches, with a slow fire under the frame.

If wild rice is not fire dried, it needs to be parched or roasted in order to preserve it, to remove the barbed awns, and to make it edible (Vennum, 1988). This serves two purposes; it destroys the germ and prevents the kernel from sprouting and hardening of the kernel loosens the tight fitting hull so it can be removed (Vennum, 1988). Before Aboriginal People had metal kettles to parch rice, they would use the scaffold method, thus effectively combining drying and parching, another possibility would have been to parch wild rice in a pit, line with stones heated by a fire in the depression (Vennum, 1988).

In order to separate the kernel from the husk, a hole was dug about a foot and a half deep with three feet in circumference (often referred as "ricing jigs") where four to five quarts of wild rice were laid, securely wrapped in moose or deer skin (Densmore, 1974; Johnson, 1969a; Stickney, 1896). The grains were then treaded upon by the "stalwart brave" until the husk was detached (Stickney, 1896). The treading of the rice resembles dancing where the weight of the entire body is not heavily placed on the feet (Densmore, 1974). The grains were cleaned in the wind (Densmore, 1974; Vennum, 1988) or by means of a birch-bark fan to remove the leftover husk and were ready for storage, which could be for many years if properly cured and stored in a dry place (Stickney, 1896). The chaff of the treading, somewhat considered a delicacy, was often kept and cooked, keeping much of the flavour of the rice (Densmore, 1974).

Wild rice is very portable, and because of this, it was a major food source for early voyageurs and fur traders (Vogel, 1990). Processing of freshly gathered rice at the harvesting site is not necessary since the grains of wild rice can be transported for some time in a damp state without damage; however processing reduces the weight of the wild rice by about one-third and the bulk by about the same, making transport easier (Johnson, 1969a). Traditionally, wild rice was cooked with meat or fish, often in soups (Densmore, 1974; Stickney, 1896; Vogel, 1990), and sometimes sweetened with maple sugar (Densmore, 1974; Vogel, 1990), blueberries (Densmore, 1974), cranberries (Stickney, 1896), or just by itself; it could be roasted and eaten dry (Jenks, 1903). The combination of wild rice, corn and fish was sometimes a favourite dish (Kuhnlein and Turner, 1991). Stickney (1896) mentions that wild rice was usually cooked ungrounded and usually without seasoning by the Ojibwa; that a small handful could be enough of a meal to feed a large family; and that if cooked into a paste it can be a good substitute for bread. Yields of wild rice using native harvesting techniques are estimated to range from 40 to 100 pounds of processed rice per acre (Lofstrom, 1987).

Wild rice served Native people in another way, it attracted vast numbers of wild fowl, thus providing another great food supply since not only did wild rice served as a decoy or as a blind (allowing the hunter to hide himself in the thick straw of the rice) making it easier to kill the birds with a club, but also made the birds fat and delicious (Stickney, 1896). Wild rice is also known to have been used as a trade item during the Fur Trade period (Kuhnlein and Turner, 1991).

4.2.2. Prehistoric Evidence of Wild Rice

It has been suggested that wild rice was introduced into the natural biota and the human economy between one and two thousand years ago (Lofstrom, 1987; McAndrews, 1969). However, it is difficult to assess the antiquity and distribution of wild rice since it has been known to have been planted in recent times in many locations as a source of food for ducks and humans (Kuhnlein and Turner, 1991).

Lofstrom (1987) argues that prior to the introduction of wild rice, human population size was limited to numbers that could be supported on resources during the winter and that intensive exploitation and storage of wild rice for winter permitted an increase in population around A.D. 800 to 1000. Population increase is thought to have had a profound impact on social organization. For example, it is thought that a shift in the archaeological record of the decline in the importance of mound building is related to increased wild rice use (Lofstrom, 1987); however, there is no evidence supporting this assumption.

Johnson (1985) suggested that large permanent Late Woodland settlement where evidence of wild rice use has been found, such as the Cooper Village site, the Wilford site, and Vineland Bay site in the Mille Lacs area of central Minnesota represents an abundance of wild rice, which provided a rich, stable economy that led to the development of large, permanent villages. On the other hand, Salzer (1974) suggests that the apparent increase in population in the lakes district in Wisconsin during late prehistoric times might be related to the discovery of the economic potential of intensive wild-rice gathering, or perhaps the introduction of maize agriculture by Mississippian and/or Oneota peoples to the south.

In total, archaeological evidence of wild rice has been reported from at least 65 archaeological sites in Eastern North America from many cultures during different time periods (Figure 10, Table 1). Wild rice is present at archaeological sites from the Archaic period until the Fur Trade period. The evidence is usually limited to a few seeds, "ricing jigs", storage pits, and parching containers; however, recently phytoliths from carbonized food residues, thought to represent evidence of wild rice consumption, have been reported from a few sites (Table 1). With only limited evidence from sites scattered across Eastern North America, it is difficult to assess the importance of wild rice in prehistoric economies.

According to Johnson (1969b), remains of wild rice threshing pits are common at archaeological sites, they consist of circular, basin-shaped pits in the subsoil of the site and on some occasions they area lined with a thick plug of unfired clay and are called "jig-pots" by the Chippewa. Charred wild rice grains are often found by flotation in threshing pit fill, fire pit fill, and the clay lining of the base of the threshing pits (Johnson, 1969b). Birk (1977a) suggested that some Sandy Lake pots in Minnesota exhibit impressions of wild rice grains which suggest that the plant was readily available where the pot was manufactured and was incorporated in the paste before firing. Johnson (1969a) argued that Sandy Lake vessels were used for cooking and parching wild rice, given that many of the sites are found near modern stands of the plant. Overfired pots from the Scott site are thought to have been used as wild rice parching containers (Cooper and Johnson, 1964).

Based on microfossil evidence from carbonized food residues, some (Hart et al., 2003; Thompson et al., 1994) have argued that they have found evidence of wild rice. Hart et al. (2003) differentiated wild rice rondel phytoliths from those produced in maize based on squared-chord distance values. However, only one comparative sample of wild rice (*Zizania aquatica*) was analyzed and other wild grasses were not examined (Hart et al., 2003). At the Ogema-Geshik site in Minnesota, Thompson et al. (1994) determined that the phytoliths in the food residues of Brainerd ware ceramics indicated the use of wild rice. They conducted a chi-square test on the rondel phytoliths in the archaeological residues and the rondels from comparative wild rice chaff and found that there were no significant differences between the assemblages (Thompson et al., 1994). Thompson et al. (1994), argue that the multitude of wild rice chaff phytolithsin the carbonized food residues, can be explained by ethnographic accounts of natives keeping the chaff after treading with the rice and cooking both together, which was considered by some as a delicacy. They found that wild rice produces a distinct assemblage of phytoliths in its glumes across time and geography, since they analyzed samples from different areas, collected during different years (Thompson et al., 1994). Even though these results are interesting and might be correct, they have to be interpreted with caution since there are no identified morphotypes for wild rice described, thus far, in the published literature.

Some inference of the antiquity of the use of wild rice by prehistoric people can be made from a few dates. For example, wild rice grains were recovered from a Late Archaic-Early Woodland burial site in Michigan date to an estimated 400 to 600 B.C. (Ford and Brose, 1975); carbonized wild rice grains associated with Middle Woodland Laurel ceramics from the Big Rice site were dated to 2000 years B.P. (Valppu, 1989; Valppu and Rapp, 2000), and wild rice grains recovered through extensive floatation from a series of Late Woodland features in Wisconsin were radiocarbon dated to A.D. 784-1227 (Arzigian, 2000). Since wild rice is known to have been cooked in birch pots or lined holes in the ground during the historic period (Vennum, 1988), therefore it is possible that it was consumed long before the invention of pottery, possibly during early Archaic times; however, it is difficult to assess this since birch does not survive well in the archaeological record.

Multiple prehistoric archaeological campsites in the Lake of the Woods area have been located over the years; however none have yielded direct evidence of wild rice use such as plant remains or processing pits (Rajnovich, 1984). The reason for the lack of evidence may be due to biases in the archaeological record rather than a reflection of non-use of wild rice since surveys did not include soil flotation or were unsuccessful when soil flotation was carried out (Rajnovich, 1984). Besides recovery, identification can also be difficult in recognizing charred wild rice grains in archaeological contexts (Rajnovich, 1984).

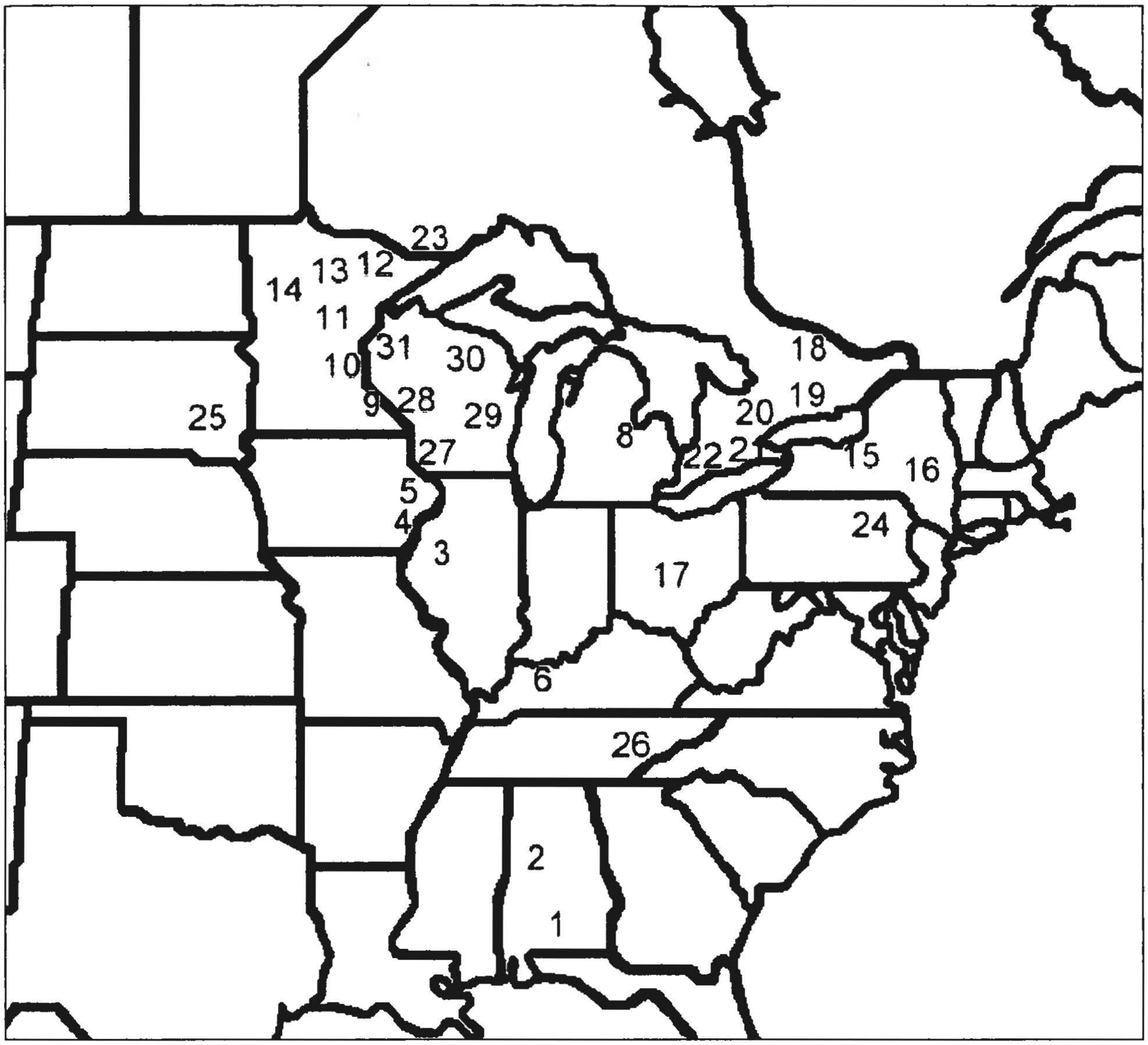

Figure 10. Archaeological sites with evidence of wild rice (*Zizania* spp.) in Eastern North America (see table 1 for caption).

Table 1. Key to Figure 10, archaeological sites with evidence of wild rice (*Zizania* spp.) in Eastern North America (modified from Crawford and Smith (2003)).

	Site	Location	Affiliated Period/Tradition/Culture	Wild Rice Evidence Type	Citation
1	Bottle Creek	Alabama	Mississippian	Seed	Scarry, 1995
2	Moundville	Alabama	Mississippian	Seed	Scarry, 2003
3	Scovill	Illinois	Middle Woodland	Seed	Munson et al., 1971
4	Sand Run Slough	Iowa	Late Archaic-Middle Woodland	Seed	Lopinot, 1987
5	Hadfields Cave	Iowa	Middle Woodland	Seed	Benn, 1980
6	Carlston Annis	Kentucky	Late Archaic	Seed	Crawford, 1982
7	Dunn Farm	Michigan	Late Archaic-Early Woodland	Seed	Ford and Brose, 1975
8	Schultz	Michigan	Middle-Late Woodland	Seed	Lovis et al., 2001
9	Bartron	Minnesota	Oneota	Seed	Gibbon, 1979
9	Bryan	Minnesota	Oneota	Seed	Zalucha, 1987
10	21AN106	Minnesota	Middle Woodland	Phytoliths	Forsberg and Dobbs, 1997
11	Aquipagueton Island	Minnesota	Late Woodland	Ricing Jig	Johnson, 1969a
11	Old Shakopee Bridge	Minnesota	Middle-Late Woodland	Seed, Ricing Jig	Gibbon, 1976
11	Petaga Point	Minnesota	Late Woodland-Early Historic	Ricing Jig, Parching Ring, Seed	Bleed, 1969; Johnson, 1969a, 1969b
11	Sawmill	Minnesota	Historic	Ricing jig	Johnson, 1969a
11	Cooper Village	Minnesota	Late Prehistoric (Oneota)	Seed	Johnson, 1985; Lucking, 1973; Schaaf, 1979
11	Vineland Bay	Minnesota	Late Prehistoric-Early Historic	Ricing Jig	Johnson, 1985
11	Wilford	Minnesota	Late Prehistoric	Seed, Ricing Jig	Schaaf, 1979, 1981
12	Big Rice	Minnesota	Laurel	Seed	Valppu, 1989; Valppu and Rapp, 2000
12	Nett Lake	Minnesota	Blackduck	Seed	Johnson, 1969b
13	Ogema-Geshik	Minnesota	Middle Woodland	Phytoliths	Thompson et al., 1994
13	Cass Lake I	Minnesota	Middle Woodland	Seed, Phytoliths	Kluth and Thomspon, 1995
13	Scott	Minnesota	Late Woodland (Blackduck)	Parching Container, Ricing Jig	Cooper and Johnson, 1964; Johnson, 1969a

Table 1. (Continued).

14	Lower Rice Lake	Minnesota	Late Woodland	Ricing Jig	Bakken, 2006; Johnson, 1969a
14	Mitchel Dam	Minnesota	Late Woodland (Blackduck, Sandy Lake)	Ricing Jig	Johnson, 1969a
14	Upper Rice Lake	Minnesota	Late Woodland	Ricing Jig, Processing Camp	Johnson, 1969a
15	Hunter's Home	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2003, 2007
15	Kipp Island	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2003, 2007
15	Simmons	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2007
15	Wickham	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2003, 2007
16	Parslow Field	New York	Archaic-Early Woodland	Seed	Asch Sidell, 2000
17	Kettle Hill Cave	Ohio	N/A	Seed	Goslin, 1952
18	Highland Lake	Ontario	Late Woodland	Seed	von Gernet, 1992
19	McIntyre	Ontario	Late Archaic	Ricing Jig	Johnston, 1984
20	Parsons	Ontario	Late Ontario Iroquois	Seed	Monckton, 1998
20	Seed-Barker	Ontario	Late Ontario Iroquois	Seed	Crawford, 1985
21	Grand Banks	Ontario	Princess Point	Seed	Saunders, 2002
22	Kelly	Ontario	Early Ontario Iroquois	Seed	Ounjian, 1998
23	MacGillivray	Ontario	Laurel	Ricing Jig	Dawson, 1980
23	Martin Bird	Ontario	Blackduck	Storage Pits	Wright, 1995
24	Catawissa	Pennsylvania	Late Woodland	Seed	King, 1999
24	Memorial Park	Pennsylvania	Late Woodland	Seed	Hart and Asch Sidell, 1996
25	Mitchell	South Dakota	Middle Missouri	Seed	Benn, 1974
26	Bacon Bend	Tennessee	Late Archaic	Seed	Chapman and Shea, 1981
26	Chota	Tennessee	Historic	Seed	Chapman and Shea, 1981
26	Iddins	Tennessee	Late Archaic	Seed	Chapman and Shea, 1981
27	Brogley Rockshelter	Wisconsin	Woodland	Seed	Tiffany, 1974
27	Hunter Channel (47Cr312a)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987

Table 1. (Continued).

27	Hunter Channel (Cr312c)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
27	Hunter Channel (Cr313a)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
27	Hunter Channel (Cr313b)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
27	Mill Coulee Shell Heap	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 2000
27	Mill Pond	Wisconsin	Middle - Late Woodland	Ricing Jig	Arzigian, 2000
28	Filler	Wisconsin	Protohistoric	Seed	Hunter, 1990
28	Olson	Wisconsin	Oneota	Seed	Hunter, 1990
28	Overhead	Wisconsin	Oneota	Seed	Arzigian et al., 1990
28	Pammel Creek	Wisconsin	Oneota	Seed	Arzigian, 1989, Arzigian et al., 1989
28	Sand Lake	Wisconsin	Oneota?	Seed	Hunter, 1990
28	Tremaine	Wisconsin	Oneota	Seed	Hunter, 1990
28	Valley View	Wisconsin	Late Prehistoric	Seed	Stevenson, 1985
29	Sanders	Wisconsin	Effigy Mound	Seed	Crawford and Hurley, 1982
30	Fishers Island	Wisconsin	Late Woodland	Seed	Moffat and Arzigian, 2000
30	Ghost Shirt Island V	Wisconsin	Late Woodland	Seed	Moffat and Arzigian, 2000
30	Robinson	Wisconsin	Late Woodland	Seed	Moffat and Arzigian, 2000
31	XY Company	Wisconsin	Historic	Seed	Oerichbauer, 1982

It has been argued that there are correlations between archaeological site locations and modern wild rice stands that are located nearby sites, especially since some sites show evidence of occupation as village sites instead of temporary camps (Johnson, 1969a; Rajnovich, 1984). Sandy Lake Ware ceramics are often associated with wild rice harvesting sites or are located where wild rice currently grows (Johnson, 1969a, 1969b; Taylor-Hollings, 1999); however they are not always found where this plant grows, especially in areas (Northeastern Grasslands and Aspen Parklands) where bison hunting is of primary focus (Taylor-Hollings, 1999).

In 1900, A. E. Jenks theorized that high population densities of native tribes reported in the area northwest of Green Bay were based on the abundance of wild rice (Wilson, 1956). Rajnovich (1984) applied a similar idea by conducting a study on the correlation between modern wild rice stands and several prehistoric sites in the Lake of the Woods area. Nearly 200 archaeological sites are correlated with modern wild rice localities, based on this circumstantial evidence, Rajnovich (1984) suggested that wild rice was harvested as early as the beginning of the Laurel phase on Lake of the Woods. Lee et al. (2004) also point out that a similar coincidence occurs between campsites and location of modern wild rice stands at several Princess Point sites in south central Ontario.

Similarly, Whitefish lake, a small lake near Thunder Bay Ontario, is surrounded by archaeological sites on the western side of the lake, as well as two sites on an island one mile from the western shore on this side of the lake that span 2000 years of human occupation (based on Laurel-Blackduck occupation of the area and a radiocarbon date from the Macgillvray site) (Dawson, 1974). Perhaps not coincidently, wild rice grows across the western portion of the lake today, and artifacts suggesting a spring-fall occupation dependent on fishing, small mammals and birds (Dawson, 1974) are present. Based on his observations of burial mounds of both Laurel and Blackduck affiliation and possibly jigging pit features, Dawson (1974) suggests that this might attest to a high local population with a subsistence base that might have been dependent on wild rice.

Johnson (1969a) describes two kinds of sites with possible association with wild rice: permanent villages and specialized harvesting and processing locations where wild rice has been found. It seems that it is possible that some sites were occupied during seasons where wild rice was not available (Taylor-Hollings, 1999), or that modern stands are located where wild rice did not grow in the past. It is possible that locations tested for sites were chosen because of the presence of wild rice in the area, or perhaps, it is also possible that because wild rice grows in many places around lakes and rivers in areas such as Minnesota and Northwestern Ontario it is most likely that it will appear as if prehistoric people established themselves where the plant grows (i.e., a false correlation).

Some (Buchner, 1979; Mason, 1981; McAndrews, 1969; Stoltman, 1973) have linked Laurel expansion to the availability of wild rice based on the evidence pointing at the availability of wild rice and changes in climatic conditions beginning during the Middle Woodland period. The availability of wild rice is thought to have been an important variable in the transition of cultures during the Middle and Late Woodland period, since wild rice may not have spread across the major lakes of Minnesota until A.D. 600-800 (McAndrews, 1969).

Ossenberg (1974) and Gibbon and Caine (1980) have hypothesized that wild rice was a factor in the shift from a diffuse subsistence pattern during the Middle Woodland period to a focal subsistence pattern in the Late Woodland period. However, this hypothesis has not been proven. It is not quite clear if wild rice spread naturally (McAndrews, 1969) or due to human involvement (Johnson, 1969a).

Arzigian (2000) notes that Middle Woodland cultures who practiced horticulture at Prairie du Chien and agricultural Oneota populations at La Crosse County in Wisconsin, both harvested wild rice as part of a mixed economy. Arzigian (2000) argues that absence of wild rice in assemblages might represent a possible absence of wild rice in the region, rather than a choice not to exploit it (the grain would have been harvested and consumed when suitable beds were present); especially since there is evidence that Woodland populations did not abandon wild rice procurement when corn was introduced. For example, she mentions the Fishers Island site feature on Minocqua Lake in the Wisconsin River Headwaters dating to A.D. 1030±80 contained both carbonized wild rice and corn (Arzigian, 2000).

Gibbon and Caine (1980) suggest that increases in population sizes might have put pressure on traditional food resources forcing them to find better means to exploit the resources around them. However, population increases is also evident in southern Minnesota following the shift to a greater reliance upon domesticated foods (Gibbon and Caine, 1980). They argue that a much larger population might have existed in the Carolinian-Canadian transition zone after A.D. 900 than in southern parts of Minnesota due to the intensive harvesting of wild rice. Wild rice subsistence is also thought to have intensified in central and northern Minnesota by A.D. 800 by the Kathio, Clam River and Blackduck phases (Gibbon and Caine, 1980).

4.3. ETHNOHISTORICAL AND ARCHAEOLOGICAL EVIDENCE OF MAIZE (*Zea mays*)

4.3.1. Ethnohistorical evidence of Maize (*Zea mays*)

Corn, beans, and squash, were known to the Iroquois and other native groups as the "Three Sisters", which were planted each year in a great ceremony by the women (Kuhnlein and Turner, 1991; Wright, 1995). Corn, beans, squash and even sunflowers were planted together. This resulted in a symbiotic arrangement, allowing the beans to grow up the cornstalks (Kuhnlein and Turner, 1991). However, for the Woodland Ojibwa, cultigens were only a small part of their diet, since they relied mostly on hunting and fishing, with some gathering of important wild foods such as wild rice (Moodie and Kaye, 1969). According to McMillan

(1995), agriculture was not practiced by the western Ojibwa, but was of some importance with groups that had contact with the Huron such as the Ottawa, which relied heavily on the use of beans, corn, and squash.

Mandan corn, cultivated by the Hidatsa from the Missouri to the Knife River, is one of the hardiest and earliest varieties of the northern flints, and is produced with minimum handling making it ideal for growing (Moodie and Kaye, 1969). It was possible to grow this variety of maize in higher latitudes under favourable conditions. Warm, well-drained levee soils are among the quickest to produce corn and offer optimum conditions, and the light, sandy soils of islands and sides of rivers which could be easily cultivated with primitive tools were preferred locations (Moodie and Kaye, 1969). In Lake of the Woods and northern Minnesota, for example, Indian gardens were located on lakesides or island sites due to the moderating effects of the large bodies of water extending the growing season by delaying frost (Moodie and Kaye, 1969).

In historic times, people in North Dakota such as the Hidatsa and Mandan have been reported to husk maize in their gardens, therefore only the cobs were consistently introduced to the village itself (Bozarth, 1993a; Mulholland, 1993). Corn cobs were often discarded or used as a fuel source or as a salt or seasoning (Bozarth, 1993a; Bozarth and Guderjan, 2004; Mulholland, 1993; Wilson, 1987). Historically, the Hidatsa ate green corn boiled on the cob, either fresh or dried and also made corn bread by pounding the green corn into a pulp and then turning them into loaves that could be baked within the coals of a fire (Wilson, 1987). The Hidatsa also ate shelled green corn, boiled with mixed beans and fats (Wilson, 1987).

Prehistoric horticulture north of the Canada-United States border may have been possible. Accounts of Buffalo Bird Woman, a Hidatsa, described by Wilson (1977) reinforces the notion that native maize varieties and other native garden cultigens can be grown on the northeastern Plains using traditional gardening techniques. Some Aboriginal varieties of maize are known to have grown within 60 to 90 days, allowing them to grow to maturity before they could be affected by frosts (Nicholson, 1990, 1991).

Moodie and Kaye (1969) mention some earliest documented occurrences of Indian horticulture north of the Upper Missouri in the southern Manitoba Lowlands and in the adjacent areas of Ontario and Minnesota during the early historic period (Figure 9). Historical accounts of Indian corn and potatoes grown at Netley Creek, near the mouth of the Red River in Manitoba, were recorded as early as 1805, and on the Assiniboine River at the Half Way Bank by 1815; however maize believed to be Mandan in origin was planted at Brandon House as early as 1796 (Moodie and Kaye, 1969). By 1822, Reverend John West noted that Indians were raising potatoes and pumpkins on the shores of Lake Manitoba, and by 1855 and 1856, Reverend James Settee observed potato fields on a garden island he called Potato Island at the north end of Lake Manitoba (Moodie and Kaye, 1969). In 1816, Daniel Harmon noted that the Ojibwa were growing corn and potatoes in Lake of the Woods; however some plantations were already established by the Ottawas by 1813 (Moodie and Kaye, 1969). In northern Minnesota, an early appearance of maize horticulture appears possibly as early as 1812 on the Roseau River, 1829 on Red Lake, and 1832 at Cass Lake (Moodie and Kaye, 1969).

4.3.2. Prehistoric Evidence of Maize (*Zea mays*)

The period from 250 B.C. to A.D. 200 is seen as the initial development of Middle Woodland period Hopewellian societies in eastern North America with large earthworks, conical burial mounds, and elaborate mortuary practices (Smith, 1989). Maize is thought to occur in eastern North America as early as 500 B.C. Direct AMS dating on carbonized kernel fragments from the Icehouse Bottom site in Tennessee and from the Harness site in Ohio suggests early dates for maize of A.D. 175 and A.D. 220, respectively (Chapman and Crites, 1987; Smith, 1989). However, dates recovered from AMS dating of carbonized food residues by Hart et al.

(2007) offer even older dates for the appearance of maize of 2270 B.P. in the Central New York State region. Based on stable isotopes and AMS dating, it has been suggested that maize was not the cause of the development of Hopewellian societies or a rapid shift to an agricultural economy; instead it is seen as a minor addition to an already well established food producing economy (Smith, 1989).

It is only six to nine centuries later (A.D. 800 to 1100) that horticultural products begin to play an important role in food producing economies in eastern North America (Smith, 1989). The shift to maize-centred agriculture, from a minor cultigen to a staple, across eastern North America, is thought to be associated with the emergence of more complex socio-political organizations (Smith, 1989). The development of maize into an eight-row variety able to grow in short seasons around A.D. 900 to 1000 might be the reason why it spread so easily across the northern latitudes of eastern North America (Smith, 1989). For example, the Initial Middle Missouri tradition, characterized as a horticulturally based population, colonized the Missouri valley as temperatures improved around A.D. 900. They lived in earthlodge villages, depended on their gardens and hunting as part of their economy (Johnson, 1993). A mixed economy based on maize, beans, squash, sunflower with hunting and fishing was well established in the Lower Great Lakes area by A.D. 1100 (Crawford et al., 1997).

The presence of cultigens has been recorded at several sites in North America (Table 2); however most northernmost sites are found south of the Great Lakes or Canadian-United States border. Sites with recorded macrobotanical evidence of maize in Canada mostly occur in southern Ontario, and are of Late Precontact (Iroquois) origin. However, a carbonized maize kernel was found at the Nyman site, a protohistoric site north of Lake Superior (Dawson, 1976c). The only other Late Woodland site in Canada with macrobotanical evidence of maize is the Lockport site in Manitoba (Schneider, 1992). Recently, microfossil remains which included maize (*Zea mays*) and possible common beans (*Phaseolus vulgaris*) from carbonized food residues were reported from several sites on the Northern Edge of the Great Plains and adjacent Boreal Forest/Canadian Shield in Manitoba (Boyd et al. 2006, 2008; Surette, 2005).

It has been suggested that horticulture might have supplemented hunting and gathering as the basis of the economy of Vickers Focus groups in southern Manitoba between A.D. 1000-1500 (Nicholson, 1990). However, there is little or no artifactual evidence of horticulture in most sites examined in southern Manitoba (Hamilton and Nicholson, 1999). The only direct botanical evidence comes from the Lockport site where some carbonized kernels, scapula hoes, and bell shaped pits have been found (Buchner, 1987; Hamilton and Nicholson, 1999, 2005; Nicholson, 1990, 1991, 1993). Indirect evidence of horticulture at most sites include ceramics affiliated with Plains Village or Plains Woodland settlements to the south, exotic materials indicative of long distance trade, possible agricultural tools, and site locations suitable for the possibility of horticulture (Hamilton and Nicholson, 2005; Nicholson, Nicholson, 1990, 1991, 1993, 1994; Nicholson and Hamilton, 1996; Taylor, 1994). Ceramics found at this site include Oneota, Initial Variant Middle Missouri, and Blackduck vessels (Boyd, 2002a; Buchner, 1987, 1988; Hamilton and Nicholson, 1999, 2005; Nicholson, 1990, 1991; Taylor-Hollings, 1999; Walde et al., 1995). The presence of possible storage pits at this site suggests the presence of surplus food (Nicholson, 1990, 1993). It has been assumed that the site shows evidence of local corn growing. However, it has also been suggested (Boyd, 2002a) that corn was carried into the site from villages further south since maize trading was known to have occurred historically. Although evidence for horticulture, or a least the consumption of cultigens, seems strong, the complete Lockport site report remains unpublished and has not yet been subjected to peer-reviewed scrutiny.

Evidence of possible horticulture is also seen at the Lowton and the Lovstrom site, two Vickers Focus sites. There is not much direct evidence of horticulture at the Lowton site, only several stone hoes recovered by local collectors and ceramics showing a mixture of Woodland

and Plains Village traits (Hamilton and Nicholson, 2005; Nicholson, 1991, 1994; Nicholson and Hamilton, 1996; Nicholson et al., 2002; Taylor-Hollings, 1999). Nicholson (1990, 1991) believes that the location of several Vickers Focus sites might have been optimal to the cultivation of hardier varieties of maize. The horticultural evidence from the Lovstrom site includes a possible bison scapula hoe, grinding stones, two scapula knives which may have been used as squash knives and some individual rim sherds displaying a mixture of both Woodland and Plains Village traits (Hamilton and Nicholson, 2005; Nicholson, 1990, 1994; Nicholson and Hamilton, 1996). The only direct evidence of corn consumption at these two sites, and several other sites in southern Manitoba, comes from a study by Boyd et al. (2006), where maize phytoliths were recovered from carbonized food residues. However, it is unclear if the maize was grown locally or acquired through trade.

Evidence of contacts with horticultural groups at these two sites includes exotic raw materials such as catlinite smoking pipes and disk/tablets from southern Minnesota (Taylor, 1994, 1996; Taylor-Hollings, 1999), Knife River Flint, Tongue River Silicified Sediment, and obsidian are indicative of trade networks with people from the Dakotas (Boyd, 2002a; Hamilton and Nicholson, 2005; Nicholson, 1991; Nicholson and Hamilton, 1996). Ceramic vessels uncommon to the area, with fabric impressed, plain wares have been found, showing a general affiliation to wares in Late Woodland sites from northern Alabama to the Upper Mississippi regions of Illinois, Iowa and Minnesota (Boyd, 2002a; Hamilton and Nicholson, 2005; Nicholson, 1991, 1994; Nicholson and Hamilton, 1996). An exotic ground stone axe and unique pottery with anthropomorphic figures not common in the area were also found at one of the sites. Among the ceramics at the Lovstrom site was a finely made Fort Yates vessel of Middle Missouri origin that might have been obtained through trade (Nicholson, 1994). Nicholson (1993) mentions that ceramics found from Vickers Focus sites indicates associations with Mississippian influenced groups from the Dakotas and southern Minnesota. Work at the "Forks" of the Red and Assiniboine rivers in Manitoba by Parks Canada also provides additional evidence for horticulture by reporting the presence of a possible prehistoric anthrosol consistent with horticultural disturbance (Pettipas, 1995).

There is much direct evidence of horticulture from archaeological sites in the Middle Missouri region of the Dakotas, Minnesota and Iowa during the late pre-contact period. This evidence includes carbonized kernels and cobs, bell-shaped pits, fortified villages, elaborate ceramics and horticultural tools (Michlovic and Schneider, 1993; Schneider, 2002). Charred cultigens have been found in as many as 12 sites in eastern North Dakota (Schneider, 2002). Excavations at the Shea site (32CS101), a late prehistoric site in southeastern North Dakota that contained charred maize and other seeds, cache pits, bison scapula hoes (Michlovic and Schneider, 1993; Schneider, 2002) and maize phytoliths (Thompson and Mulholland, 1994). It has been interpreted as a seasonal camp of prehistoric bison hunters who supplemented their diet with garden produce (Michlovic and Schneider, 1993, Schneider, 2002).

Historically, the Mandan and Hidatsa lived in large fortified villages near the Knife and Heart rivers diverging from the Missouri River in North Dakota, they depended on a combination of bison hunting and cultigens with wild plant foods as a minor supplement (Boyd, 1998). Mandan and Hidatsa were also known to exchange maize for bison with hunter gatherer groups, thus requiring less energy expended on hunting and solidifying economic alliances (Boyd, 1998). Siouan groups in central Minnesota were known to practice a mixed economy, with seasonal bison hunting, limited horticulture, wild rice and fish harvesting (Birk and Johnson, 1992). Dakota groups in southern Minnesota had an economy based on deer, elk, moose, and other mammals, fish, birds, wild rice, maple sugar and other wild plants, as well as limited horticulture including corn and tobacco (Whelan, 1990).

Table 2. Cultigens found in some northernmost sites in North America.

Site	Location	Affiliated Culture/Period/Tradition	Cultigens	Citation
Koster	Illinois	Archaic	Squash	Asch and Asch, 1985
Cahokia	Illinois	Cahokia	Squash	Fritz, 1994
Broken Kettle West (13PM25)	Iowa	Great Oasis	Maize, Squash	Cutler and Blake, 1973
Williams (13PM50)	Iowa	Great Oasis	Maize, Squash	Williams, 1975
Cowan (13WD88)	Iowa	Great Oasis	Maize, Squash	Dunne, 1999
Brewster (13CK15)	Iowa	Mill Creek	Maize, Squash, Beans	Stains, 1972
Chan-Ya-Ta (13BV1)	Iowa	Mill Creek	Maize, Squash, Beans	Wegner, 1979
Phipps (13CR21)	Iowa	Mill Creek	Maize, Squash	Schroeder, 1995b
Milford (13DK1)	Iowa	Oneota	Maize, Squash	Tiffany and Anderson, 1993
Blood Run (13LO2)	Iowa	Oneota	Maize, Beans	Tolmie and Green, 1992
Dixon (13WD8)	Iowa	Oneota	Maize, Squash, Beans	Schroeder, 1995a
Sharrow	Maine	Archaic	Squash	Asch Sidell, 1999; Hart and Asch Sidell, 1997
Lockport	Manitoba	Late Woodland	Maize	Schneider, 1992
Schultz	Michigan	Early-Middle Woodland-Late Woodland	Maize, Squash	Lovis et al., 2001
Green Point	Michigan	Late Archaic-Early Woodland	Squash	Ozker, 1982; Wright, 1964
Juntunen	Michigan	Late Woodland	Maize	Yarnell, 1964
Cambria	Minnesota	Cambria	Maize	Gibbon, 1993
Price	Minnesota	Cambria	Maize	Gibbon, 1993
Cooper	Minnesota	Late Prehistoric	Squash	Johnson, 1985; Lucking, 1973; Schaaf, 1979
King Coulee	Minnesota	Late Archaic-Early Woodland	Squash	Perkl, 1998
White Buffalo Robe (32ME7)	North Dakota	Late Woodland-Historic	Maize, Squash, Beans	Nickel and Jones, 1980
Bagnell (32OL16)	North Dakota	Coalescent	Maize, Squash, Beans	Nickel, 1977
On-A-Slant (32MO26)	North Dakota	Protohistoric Mandan	Maize, Squash, Beans	Aaberg, 1997
Boyley (32MO37)	North Dakota	Protohistoric Mandan	Maize, Squash, Beans	Shay and Kapinga, 1993
Shea (32CS101)	North Dakota	Plains Village	Maize	Michlovic and Schneider, 1993

Table 2. (Continued).

Leimbach	Ohio	Middle Woodland	Squash	Ozker, 1982
Nyman	Ontario	Late Woodland (Blackduck and Selkirk)	Maize	Dawson, 1976c
Grand Banks	Ontario	Late Woodland I	Maize	Smith and Crawford, 1997
Lone Pine	Ontario	Late Woodland I	Maize	Smith and Crawford, 1997
Auda	Ontario	Pickering Phase Iroquois	Maize	Kapches, 1987
Porteous	Ontario	Early Iroquois	Maize	Stothers and Yarnell, 1977
Hibou	Ontario	Late Woodland	Maize	MacDonald and Williamson, 1995
Calvert	Ontario	Early Iroquois	Maize, Squash	Ounjian, 1998; Timmins, 1997
Dymock I, II	Ontario	Early Iroquois	Maize, Squash	Cooper, 1982
Providence Bay	Ontario	Early Historic	Maize	Conway,1989; Crawford, 1989
Shawana	Ontario	Early Iroquois	Maize	Crawford, 1989
Hunter's Point	Ontario	Late Woodland	Maize	Goode, 1993
Highland Lake	Ontario	Iroquois	Maize	von Gernet, 1992
Auger	Ontario	Iroquois	Maize, Beans	Monckton, 1992
Lawson	Ontario	Iroquois	Maize, Beans	Monckton, 1992
Memorial Park	Pennsylvania	Archaic	Squash	Asch Sidell, 1999; Hart and Asch Sidell, 1997
Meadowcroft	Pennsylvania	Archaic	Squash	Hart and Asch Sidell, 1997
39FA23	South Dakota	Middle Missouri	Maize	Adair, 1996
Walth Bay (39WW203)	South Dakota	Plains Village	Maize, Squash, Beans	Nickel, 1977
Mitchell	South Dakota	Initial Middle Missouri	Maize, Squash, Beans	Benn, 1974
Dietz	Wisconsin	Effigy Mound	Maize	Baerreis and Nero, 1956

Evidence of prehistoric maize consumption and production in southern Ontario is supported by the presence of charred grains (Smith and Crawford, 1997), isotope analysis of human bones (Katzenberg et al., 1995) and prehistoric carbonized food residues on ceramics (Morton and Schwarcz, 2004), thus indicating that corn was a significant part of the diet. Crawford et al. (1997) dated charred maize remains associated with the Princess Point culture at the Grand Banks site in southern Ontario between A.D. 540 and 1030.

Additional evidence of maize consumption around the study area comes from charred cob remains associated with the Effigy Mound culture recovered from the Dietz site in Dane County, Wisconsin (Baerreis and Nero, 1956). Evidence of Eastern Eight Row or Northern Flint maize was also recovered at the Cambria and the Price sites in Minnesota, as well as some storage pits and scapula hoes (at the Price site only) (Gibbon, 1993).

Schneider (2002) argues that the presence of charred maize cupules and/or cob fragments at several sites in the northeastern Plains negates the idea that maize was transported to these sites from the Missouri River valley earthlodge village sites rather than having local origins.

> *"If maize transport took place, then "maize on the cob" was transported for distances ranging from 170 km (to the James River locality in southeastern North Dakota) to 560 km (to the Lockport site in south central Manitoba) from the closest identified horticultural village sites along the Missouri River in North Dakota. It is more reasonable, and the accumulated archaeological, historical, and experimental evidence strongly supports the suggestion, that maize was cultivated by indigenous prehistoric gardeners in a variety of locations throughout the northeastern Plains from circa A.D. 1200 to A.D. 1805 (Schneider, 2002: 45)."*

Schneider (2002) examines five reasons why the presence of cultigens during the late prehistoric period on the northeastern Plains has not fully been accepted:

> *"1. A biased view of the archaeological sites of this subarea due to their small size, their lack of fortifications ditches and earthlodge depressions, their lack of cache pits, the presence of few gardening tools such as bison scapula hoes, and the scant evidence for cultigens as compared to the situation found at the Plains villages sites of the Missouri River valley. 2. The long-held belief that the climate*

> *of the subarea was not conductive to horticulture, particularly maize horticulture. 3. Failure to use appropriate field techniques for the recovery of archaeobotanical materials. Unfamiliarity with early historic accounts of native horticulture in the subarea. 5. The lack of experiments to demonstrate the feasibility of native horticulture within the subarea (Schneider, 2002: 33-34)."*

These reasons might explain why some archaeologists tend to be reluctant to suggest the presence of horticulture on the northeastern Plains, even when cultigens have been found during site excavations (Schneider, 2002).

4.4. ADDITIONAL WILD AND CULTIVATED PLANTS USED DURING THE HISTORIC AND PREHISTORIC PERIOD

4.4.1. Ethnographic uses of Wild Plants

The economic behaviour of hunter-gatherer groups is guided by the minimization of effort or the maintenance of its expenditure within a predefined range (Jochim, 1976). Therefore, efficiency and minimal effort in resource acquisition is related to the distribution, rarity or abundance, and ease of accessibility to resources (Wall, 1979). Unequal distribution of resources over the landscape and seasonal variations of economic resources can have a great impact on the regional settlement patterns of various groups (Wall, 1980b). Jochim (1976) argues that choices involved in which resources are utilized tends to structure the distribution of band composition and populations of hunter-gatherers. Therefore, the result of a consistent pattern in settlement location is directly tied to resource procurement (Wall, 1980b).

Wild rice (*Zizania palustris*) is one of many economically important plants that are part of the local "supermarket" of the wetlands of Northwestern Ontario. It is possible that other wetland resources than wild rice were the primary reason for waterside settlement (Lee et al., 2004). Historically we know that people ate berries (blueberries, raspberries, currants, cranberries, cherries, etc.) as well as many other plants that grow in the area during different times of the year (Densmore, 1974; Newmaster et al., 1997); however these foods would not have been staples, only as additions to the diet. Economic or highly starchy plants that could have been eaten along with wild rice, or at least could have supplemented wild rice during prehistoric times in the area are examined in this section. In addition, potential horticultural plants, other than maize, that might have been available in the study area during prehistoric times are also discussed.

Many archaeological sites in Northwestern Ontario are located near modern wild rice (*Zizania palustris*) stands, or at least at good fishing locations. Often where wild rice grows there are also other plants that are economically valuable. Historically, the Ojibway, Cree, and other Native cultures made use of cattails (*Typha latifolia*), broad-leaved arrowhead (*Sagittaria latifolia*), and yellow pond lilies (*Nuphar variegatum*) that were readily available, easy to collect and very high in starch (Johnson et al., 1995; Newmaster et al., 1997).

Cattails (*Typha latifolia*) are known as one of the best and most versatile wild edible plants and are found around the shores of lakes, shallow marshes, swamps, slow moving or standing water all across Canada (Kuhnlein and Turner, 1991; Newmaster et al., 1997; Peterson, 1977). During the spring, cattail (*Typha latifolia*) rhizomes were cooked and eaten like potatoes and made excellent flour, similar to corn starch (Johnson et al., 1995; Kuhnlein and Turner, 1991; Newmaster et al., 1997). The rhizomes could only be eaten in the spring or early summer since they would get woody later in the year; however the roots could be crushed into water during fall, winter or early spring separating the starch from the fibers so it could be used as flour (Kuhnlein and Turner, 1991; Peterson, 1977). However, the green spikes could be eaten like corn on the cob, and the young stems "would be eaten like asparagus" (Arnason et al., 1981; Johnson et al., 1995; Newmaster et al., 1997; Peterson, 1977). Large amounts of pollen can be collected easily by shaking the heads and makes a protein rich flour when mixed half and half with other sources of flour (Arnason et al., 1981; Peterson, 1977). Cattails are known to have been eaten by both the Ojibwa and the Cree historically (Kuhnlein and Turner, 1991).

Broad-leaved arrowheads (*Sagittaria latifolia*) (Duck Potatoes, Wapato, Indian Swamp Potato) are plentiful and found on the edges of marshes, lakes, ponds and streams (Kuhnlein and Turner, 1991). Native People used the rhizomes throughout the spring and summer and collected the edible egg-shaped tubers (2-5 cm in diameter) in the autumn (Densmore, 1974; Johnson et al., 1995; Kuhnlein and Turner, 1991; Newmaster et al., 1997; Peterson, 1977). The tubers are light brown on the outside and white on the inside like the common potato we eat today (Kuhnlein and Turner, 1991). Many Indigenous groups are known to have eaten arrowheads historically including the Iroquois and the Ojibwa in Ontario (Kuhnlein and Turner, 1991). Historically the tubers of arrowheads were used as trade with various native groups; some groups would own patches of land where the plant grows and family groups would camp besides their claimed harvesting sites for a month or more (Kuhnlein and Turner, 1991). The tubers could be gathered in the spring, after flowering or in the fall by pulling up the plant with the tubers attached on the side of a canoe or by dislodging the tubers with their feet in the mud allowing the tubers to float to the surface (Kuhnlein and Turner, 1991). The tubers can be stored fresh after collection for several months (Newmaster et al., 1997). They can be boiled, baked in hot ashes or underground pits, eaten immediately or dried for long term storage (Newmaster et al., 1997). The tubers are unpleasant when eaten raw, but delicious when cooked (Peterson, 1977) and can taste very sweet when pit-cooked (Newmaster et al., 1997).

Yellow pond lilies (*Nuphar variegatum*) are found in lakes ponds, streams and rivers from British Columbia to the Atlantic Coast (Kuhnlein and Turner, 1991). The seeds can be fried like popcorn or cooked like sweet corn, and the large rhizomes can be eaten like potatoes either by being boiled or roasted (Kuhnlein and Turner, 1991; Newmaster et al., 1997; Peterson, 1977). The rhizomes were often collected from muskrat houses (Newmaster et al., 1997).

There are over 380 grass species native to Canada that are found in various locations (Kuhnlein and Turner, 1991). Some are edible while the majority are not, although native communities used unpalatable species such as big bluestem (*Andropogon* sp.), Canada bluejoint (*Calamagrostis* sp.), and wheatgrass (*Pascopyrum* sp.) for other means than food such as bedding, or other weaved products (Moerman, 1998). Grasses make up some of the most economic plants found worldwide such as wheat, rye, barley, maize, rice, bamboo, and the sugar cane. However, in Canada, Indigenous Peoples exploited only few grasses traditionally (Kuhnlein and Turner, 1991). Maize (*Zea mays*) and wild rice (*Zizania* spp.) were the only grasses used in any quantity (Kuhnlein and Turner, 1991). Edible grasses that are known to have been consumed by native traditional groups in Canada or the adjacent United State that might have been used in this study area are mentioned below.

The seeds or grains of ricegrass (*Oryzopsis* sp.) are known to have been used as flour and often mixed with corn meal or made into breads or cakes (Moerman, 1998). To a lesser extent, seeds of rough bentgrass (*Agrostis* sp.), slough grass (*Beckmannia* sp.), brome (*Bromus* sp.), drooping woodreed (*Cinna* sp.), tufted hairgrass (*Deschampsia* sp.), wild rye (*Elymus* sp.), teel lovegrass (*Eragrostis* sp.), fescue (*Festuca* sp.), manna grass (*Glyceria* sp.), foxtail barley (*Hordeum* sp.), junegrass (*Koeleria* sp.), marsh muhly (*Muhlenbergia* sp.), witchgrass (*Panicum* sp.), reed canary grass (*Phalaris* sp.), meadow grass (*Poa* sp.), puffsheath dropseed (*Sporobolus* sp.), and spike trisetum (*Trisetum* sp.) are also known to have been used as food by various native populations (Moerman, 1998).

Grasses growing in close proximity to wild rice in Northwestern Ontario (Boreal Forest) include: *Phragmites australis* (common reed), *Glyceria* sp. (manna grass), *Leersia oryzoides* (rice cut grass), *Oryzopsis* sp. (indian rice grass) (Newmaster et al., 1997). *Phragmites australis* can be confused with wild rice, but wild rice has dangling, hairless spikelets, and it is an annual grass with short roots that are easily pulled out. The reeds were often used for mats by the Ojibway (Newmaster et al., 1997). The young stem of *Phragmites*, while still green and fleshy can be dried and pounded into a fine powder, which when moistened can be roasted like marshmallows (Johnson et al., 1995; Peterson, 1977), and the starchy seeds and rootstocks can also be used for flour (Moerman, 1998; Peterson, 1977).

Leaves of salt grass (*Distichlis* sp.) have been used as "salt" when ashed, the leaves and stems have also been known to have been used as food (Moerman, 1998). Wild rye (*Elymus* sp.) and other grasses were used by some native groups as lining of cooking pits, as well as being dispersed between layers of food (Kuhnlein and Turner, 1991). Dried grass was also used to line storage baskets for berry cakes and dried roots, and to intersperse between layers of dried berries and other food being stored (Kuhnlein and Turner, 1991). It is possible that microfossils or macrofossils of non-edible grasses made their way onto archaeological artefacts depending on how their food was processed, stored or handled (Kuhnlein and Turner, 1991; Moerman, 1998).

4.4.2. Archaeological Evidence of Squash and Beans

The earliest evidence of squash in an archaeological site in Eastern North America comes from the Koster site in west-central Illinois from a Cucurbita rind dated back to approximately 7100 B.P. (Asch and Asch, 1985). Evidence of Late Archaic consumption of squash also comes from cucurbit rinds found at the Sharrow site in Maine and the Memorial Park site in Pennsylvania dating to the fourth millennium B. C. (Crawford and Smith, 2003). The distribution of some of the earliest archaeological sites with evidence of Cucurbita south of the Great Lakes area; is illustrated by Monaghan et al. (2006) and Smith (1989). Some of the most northern sites (Table 2) illustrated by Monaghan et al. (2006) showing early evidence of *Cucurbita* are the Green Point (Ford, 1973; Wright, 1964) and Schultz (Lovis et al., 2001) sites in Michigan, and the King Coulee (Perkl, 1998) site in southeastern Minnesota. Evidence of squash can also be found in various Plains Village sites. Squash seeds found in a leather pouch associated with a female burial dated to approximately A.D. 800 found by the Sheyenne River, in

North Dakota offers some of the earliest evidence of horticulture (Gregg, 1994). Evidence of squash seeds were also found at the Cahokia site in Illinois (Fritz, 1994).

There is growing evidence of common beans appearing at various sites in the Northeast United States during the early Late Woodland period in North and South Dakota, Iowa, Indiana, Illinois, Ohio and Kentucky, as well as other states only after A.D. 1300 (Table 2), which suggests that it did not accompany maize during its adoption (Hart and Scarry, 1999). Archaeobotanical remains such as seeds from Iowa (Schroeder, 1995a, 1995b), as well as from microfossil remains such as possible starch granules from sites in Manitoba (Boyd et al., 2006; Iriarte et al., 2004; Surette, 2005) and phytoliths (Bozarth, 1990) recovered from a Late Precontact site in Kansas support that beans were consumed during prehistoric times.

4.5. SUMMARY

Wild rice has long been recognized by early Europeans as an important food source consumed by native communities who occupied southern and northern Ontario, as well as the northern half of the states surrounding the Great Lakes (Ford and Brose, 1975). However, there is very little archaeological evidence of wild rice at sites, due to floatation techniques not employed at sites or because of poor preservation. However, there is limited information available from carbonized grains found at some sites, roasting pits, threshing pits, vessels used for roasting, impression of grains on clay pots, and the recovery of phytoliths from carbonized food residues.

Many arguments for the movements and dispersal of various groups in the Lake of the Woods and adjacent area seem to rely on the role of wild rice. It is true that for Historic native populations, wild rice was an important food, but this does not necessarily hold true for prehistoric populations. It is possible that wetland resources (e.g., waterfowl, cattail, beaver, fish, etc.) other than wild rice were the primary reason people established themselves where wild rice stands grow (Lee et al., 2004).

Even though carbonized grains recovered from archaeological sites seem like compelling evidence for the consumption of wild rice, it is possible that the grains were simply removed from the clay while making pottery and carbonized in the fires. Impressions of wild rice grains on ceramics could simply be forgotten grains that were not removed from the cleaning of the clays, since there is no indication that they were incorporated in the clay on purpose. Furthermore, it has not been verified that the actual impressions are from wild rice grains.

Like wild rice, maize has also been suggested as the reason why there is a population surge during the late woodland; we know that maize became a staple in many Late Woodland economies. However, it is not known if wild rice also became a staple. It is possible that the shift in culture and population during the Late Woodland period occurred because of a mixed economy based on wild rice and maize.

The presence of squash has been around south of the Great Lakes area for a long time, therefore is seems likely that these produce might have made it further north during prehistoric times; however beans seem to be a recent addition in the diets of Native Peoples in North America, and therefore its presence would only be found later at sites in the study area. Based on the ethnographic data it is likely that prehistoric cultures made use of grasses other than wild rice, especially since wild rice is only collected during the fall. Therefore it might seem likely that they made use of other starchy seeds throughout the summer, which might complicate things when looking at the microfossils, although this is why having a good comparative collection is important.

CHAPTER 5. MICROFOSSIL ANALYSIS: AN OVERVIEW OF PHYTOLITHS AND STARCH GRANULES AS DIAGNOSTIC TOOLS

5.1. INTRODUCTION

Many researchers have used phytoliths in order to reconstruct past diet and environments (Bozarth, 1987; Doolittle and Frederick, 1991; Fredlund and Tieszen, 1994; Rovner, 1983). Macrofossil analysis at archaeological sites has been an important tool in determining past diets; however, very often only a few macrofossils survive (Boyd, 2002a) or are not collected during excavation depending on sampling technique (Spiedel, 1989). In contrast, phytoliths are very resilient and can survive for a very long time (Prasad et al., 2005) and can be easily sampled. Phytolith assemblages have been used to provide evidence of plants consumed at sites where the macrobotanical evidence suggested otherwise (Boyd et al., 2006; Pearsall, 2003). However, not all plants known to have been consumed historically in North America produce phytoliths in their consumable parts, therefore other lines of evidence must be considered such as starch analysis (Boyd et al., 2006). This chapter explains the method of phytolith and starch analysis and how they can be applied to paleoenvironmental and paleodiet reconstruction.

5.2. PHYTOLITHS

5.2.1. History, Theory, Methods of Identification and Problems

In general, the field of phytolith study is still at a younger stage of development compared to palynology (Piperno, 1988). Compared to phytoliths, which were only discovered in the 1830s and saw their first use in paleoecological work only after the mid 1950s (Piperno, 1988), palynomorphs (pollen and spores) were discovered in 1640 (Traverse, 1988) and their use in paleoecological studies dates back to the early 20th century (Strömberg, 2004; Von Post, 1916), with a significant development in the field by the use of palynological analysis by the oil industry in the 1930s (Strömberg, 2004; Traverse, 1988). However, since the 1970s, phytolith research has attained a prominent position in archaeology and Quaternary paleoecology (Piperno, 1988).

Many researchers in various areas of the world have advanced phytolith analysis beyond its introductary stage, allowing for a more precise identification of important crop plants in sediments or soils (Bozarth, 1987; Iriarte, 2003; Pearsall et al. 2003, 2004). Phytoliths have been used to answer many different types of questions such as whether certain cultigens were present at various archaeological sites, what kind of vegetation grew in an area, and what climate prevailed in a region (Strömberg, 2004). However, with its relatively short history, phytolith research is lacking in standardization in many areas, including extraction techniques, identification and analytic methods (Strömberg, 2004).

Phytoliths are opal silica casts of epidermal cells in growing plants. The silica needed to form these casts is carried up through the plant from groundwater as monosilicic acid (H_4SiO_4), it is absorbed by plants roots, carried to the aerial organs in the transpiration stream by the water-conducting tissue called the xylem (Piperno, 2006), fills in the cells or cell walls, solidifies, and then retains the cell shape after the organic tissue has decayed or burned (Boyd, 2002b, 2005; Bozarth, 1987, 1993a; Bozarth and Guderjan, 2004; Ollendorf et al., 1988; Pearsall, 1982, 1994; Rovner, 1983; Zheng et al., 2003).

Phytoliths can be found in most parts of the plant, such as the stems, leaves, roots and even some parts of the seeds (Bozarth, 1993a; Bozarth and Guderjan, 2004; Pearsall, 1982; Piperno, 2006; Rovner, 1983). The major functions of phytoliths in plants are thought to be for structure, physiology and protection (Piperno, 2006). The production of phytoliths in plants is due to two mechanisms: one due to genetics and physiology and the other by local climate and growing conditions (Piperno, 2006). It is important to note that not all plants produce phytoliths (Piperno, 2006). It is also important to note that plants of a single species can contain different amounts of phytoliths when grown in different environments (Piperno, 2006).

Sampling for phytoliths in archaeology is usually done in well-defined, controlled contexts such as hearths (Bozarth, 1993a; Mulholland, 1993; Rovner, 1983), burial pits, closely spaced intervals on a house floor, buried soils (Boyd, 2002b), stratified middens, cooking residues (Jones, 1993; Hart et al., 2003), dental calculus (Ball et al., 1999; Buchet et al., 2001; Lalueza et al., 1996; Pearsall et al., 2003; Staller and Thompson, 2002; Walshaw, 1999), bone and stone tools (Kealhofer et al., 1999; Pearsall et al., 2004b). Phytoliths can also be identified from soils and sediments from lakes or similar sources in order to help reconstruct past environments (Blinnikov, 2005; Fredlund and Tieszen, 1994; Grave and Kealhofer; 1999; Lentfer and Boyd, 1998, 1999, 2000; Lu and Liu, 2003, 2005; Lu et al., 2006; Parr, 2002; Singh, 2007; Strömberg, 2002, 2004).

Fearn (1998) used phytolith analysis in sediment to determine if grass pollen came from a wet or dry environment, as well as determining changes in the environment such as erosion and mixing either by natural (hurricanes) or human intervention. Fearn (1998) observed that dumbbell shaped phytoliths dominated in dry prairies, while rondel shaped phytoliths increased along the waterlogging/salinity gradient and dominated in salt marshes. Therefore, changes in rondel/bilobate ratio in an area may be indicative of changes in moisture, due to natural causes, or as a result from human activity (as a result of horticulture or introduction of wild rice in the area for example). This might allow researchers to trace the diffusion of culturally important foods such as corn and wild rice. In another study of grasses in coastal environments, Lu and Lui (2003) found that rondel/saddle ellipsoids were most common in grasses that live in salt marshes, whereas rondel and spool/horned towers were most common in grasses from brackish marshes, and flat towers and two horned forms were most common in sand dunes.

Identification of phytoliths is usually done by comparison of forms extracted from modern plants and by using a phytolith key based on studies of phytolith morphology and classification (Blackman, 1971; Bonnett, 1972; Bozarth, 1993b; Brown, 1984; Fredlund and

Tieszen, 1994; Mulholland, 1989; Pearsall, 1982; Piperno and Pearsall, 1984; Rovner, 1983; Twiss et al., 1969). Comparative phytoliths tend to be extracted from plant materials by wet and dry ashing (Parr et al., 2001) or by acid digestion (Hart et al., 2003). It is advised that to accurately examine phytoliths they must be rotated to view their three-dimensional morphology (Mulholland, 1989; Pearsall et al., 2003). It is important to have many criteria to identify them such as size, shape and quantity (Brown, 1984; Doolittle and Frederick, 1991). Phytoliths in soil or sediment samples can also be difficult to detect due to silts and clays that can obscure the final preparation; this is why it is important that researchers continue to devise new methods to separate them from other particles in soil or sediment (Lentfer and Boyd, 1998, 1999, 2000; Parr, 2002; Zhao and Pearsall, 1998).

Phytolith size can be affected by variations in moisture (Brown, 1984). Phytoliths of plants in different geographical regions or habitats can vary widely in amounts of morphological types (Strömberg, 2004). Because certain plants might demonstrate alternate ecological preferences from one area to another, this might also be reflected in the morphotypes they produce (Strömberg, 2004). It is therefore important to build a reference collection of plants that currently grow in the area of study. This allows for the development of a classification system that is relevant to the analysis.

The production of pollen and spores is uneven in plants. A plant produces one, or rarely, two types of palynomorphs (Strömberg, 2004). In comparison, the phytolith production in plants varies; some plants such as grasses can produce a lot of phytoliths types whereas others produce very little (Barboni et al., 1999; Twiss et al., 1969). In light of this, there can be a bias towards the recovery, especially in sediments, of plants that are high producers of phytoliths (Strömberg, 2004). Because a plant can produce many different phytolith types (multiplicity) that are specific to the plant and/or many basic phytolith types that are found in many plants (redundancy), developing species specific taxonomies can be difficult (Barboni et al., 1999;

Brown, 1984; Mulholland, 1989; Strömberg, 2004). This might be the reason why many researchers prefer pollen analysis, since it may seem more straightforward. Generally, broader plant groups are distinguished based on phytoliths, such as trees versus grasses; however, some species do have unique phytolith morphotypes (Barboni et al., 1999; Strömberg, 2004).

The transportation of phytoltihs by wind or water can potentially lead to sorting of phytoliths of differing size, shape, and specific gravity (Strömberg, 2004). Fine sand to silt sized phytoliths in habitats ravaged by fires can become part of the aerosol and become subject to lateral movement (Fredlund and Tieszen, 1994; Twiss et al., 1969). However, most phytoliths are released directly into soils or sediments, not in the air. Piperno (2006) suggests that in most cases a large proportion of the phytolith record represents highly localized, in situ, deposition.

Transportation of phytoliths by streams is not well studied (Piperno, 1988; Strömberg, 2004), but most likely affects the assemblage in sediments since the remains of plants bordering the sides of streams and rivers are likely to be transported into lakes. Another source of non-local phytoliths may occur through the dung of grazing animals (Fredlund and Tieszen, 1994). Besides biases in production and transport, one also has to consider biases due to taphonomy (chemical or /and mechanical weathering), since larger phytoliths will tend to be damaged, and some phytoliths will tend to dissolve before others (Strömberg, 2004). Similar to pollen, where differential destruction in soils can cause a skew in the pollen record because they tend to preserve poorly, phytoliths are also subjected to taphonomy in response to chemical and mechanical breakdown in soils (Pearsall, 2000; Strömberg, 2004).

5.2.2. Cross Phytoliths

Grass phytoliths can generally be identified to the subfamily level (Boyd, 2005; Brown, 1984; Twiss et al., 1969). Phytoliths can be used for separation between forest and grassland, C3 and C4 grasslands and, among the C4 grasslands those dominated by the subfamily

Chloridoideae and those by Panicoideae (Barboni et al., 1999). Types of grass phytolith that researchers have focused on in the past, which are still used to identify plants, are called crosses.

For the study of maize (*Zea mays),* most researchers in the past have focused on a method of identification of diagnostic cross-shaped phytoliths that are commonly produced in the leaves (Bozarth and Guderjan, 2004; Doolittle and Frederick, 1991; Iriarte, 2003; Mulholland, 1990, 1993; Pearsall, 1978, 1982, 1993, 1994, 2003; Pearsall and Piperno, 1990; Piperno, 1984, 1993a; Rovner, 1983; Russ and Rovner, 1989; Umlauf, 1993). Cross-shaped phytoliths are also produced in the Panicoideae subfamily of grasses and a few species of the bamboo subfamily (*Buadua angustifolia*) (Bozarth and Guderjan, 2004).

Eight types of three-dimensional structures, called variants and size criteria have been developed to distinguish maize at archaeological sites from other grasses in South and Central America (Bozarth and Guderjan, 2004; Pearsall and Piperno, 1990; Piperno and Pearsall, 1993b). Maize cross-shaped phytoliths are larger (≥ 16 μm) than other native grasses in South and Central America and are relatively abundant (Doolittle and Frederick, 1991; Pearsall and Piperno, 1984, 1990; Rovner, 1983). The cross bodies are square to rectangular, having an indentation on three of its four sides (Pearsall, 1982; Rovner, 1983).

Questions have been raised by many researchers on the usefulness of cross-shaped phytoliths as indicators of maize due to its diverse criteria and inconsistencies (Doolittle and Frederick, 1991; Staller, 2003). Caution is suggested when looking in areas where teosinte (*Zea mays mexicana*), a wild ancestor of maize, existed since it has cross-shaped phytoliths that overlap in size and morphology with maize (Bozarth and Guderjan, 2004; Rovner, 1983). Also, not all varieties of maize produce cross-shaped phytoliths, therefore it is not possible to detect all maize varieties with this method (Rovner, 1983). Ridged dumbbell phytoliths produced in the leaves of maize have been used in maize identification, although caution is warranted since many grasses produce dumbbell phytoliths (Bozarth, 1993a; Mulholland, 1993). Mulholland (1990) reports that crosses that were previously thought to be corn-specific are found in wild plants such as *Arundo donax*.

Increased moisture could also potentially increase the size of cross bodies in wild grasses (Brown, 1984). Therefore, it is wise to assess past vegetation and climate in each area before using this method because it could provide a false signature for maize (Doolittle and Frederick, 1991; Rovner, 1983; Piperno, 1979). Differences have also been noted in individual leaves of maize, suggesting that maize leaves can contain cross-shaped phytoliths of different sizes during different stages of growth (Doolittle and Frederick, 1991). Another interesting observation is that variations in size and shape of maize phytoliths might occur if the plant was thinned during its growth (Doolittle and Frederick, 1991). Samples recovered from the base, tip and blades of the leaves of various maize varieties were also shown to produce cross-shaped phytoliths of different sizes (Mullholland et al., 1988, 1990). Therefore, it seems likely that the recovery of cross types in the phytolith assemblages can be affected by what part of the plant was used. Due to the difficulties that can arise in differentiating the crosses found in maize from other wild grasses, rondel phytoliths have also been examined.

5.2.3. Rondel Phytoliths

Grass phytoliths have been examined by a multitude of researchers (Barboni et al., 1999; Blackman, 1971; Blinnikov, 2005; Bonnet, 1972; Bozarth, 1993b; Brown, 1984; Fearn, 1998; Fredlund and Tieszen, 1994; Hart et al., 2003; 2007; Lu and Liu, 2003, 2005; Lu et al., 2006; Mulholland, 1989, 1993; Mulholland et al., 1988, 1990; Ollendorf et al., 1988; Pearsall, 1982, 1993, 2002, 2003; Pearsall and Piperno, 1990; Pearsall et al., 2003, 2004a, Piperno, 1984, 2003; Piperno and Pearsall, 1993a, 1993b; Russ and Rovner, 1989; Singh et al. 2007; Staller, 2003; Staller and Thompson, 2002; Strömberg, 2002, 2004; Thompson and Mulholland, 1987, 1993; Thompson et al., 1994; Twiss et al., 1969; Walshaw, 1999); however, only a few have focused on rondel types. Wavy-top and ruffle-top rondels, are described types that have received a lot of attention since they tend to be found only in maize cob phytoliths, and are therefore good indicators of this cultigen at archaeological sites (Boyd et al., 2006; Iriarte et al., 2004; Pearsall, 2002; Pearsall et al., 2004a, 2004b; Pohl et al., 2007; Staller and Thompson, 2002; Surette, 2005).

There appears to be some confusion in how rondel phytoliths are defined. Twiss et al. (1969) first noticed that circular to oval phytoliths were the most characteristic of the phytolith assemblages of the Festucoid sub-family of grasses (Figure 11). Mulholland (1989) first referred to these circular to oval phytoliths as rondels, which seemed to dominate in all maize cobs. Rondels also appear in Brown's (1984) key where they are referred to as double outline phytoliths or perhaps short trapezoids (see Blinnikov (2005) and Mulholland (1989)), and in Kondo et al. (1994) and Wang and Lu (1993) where they are referred to as hat/cone-shaped phytoliths (see Lu and Liu, 2003).

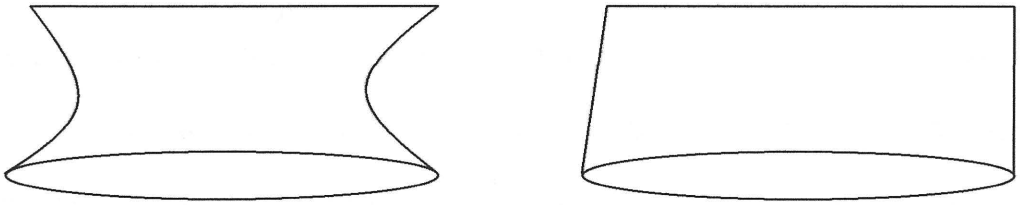

Figure 11. Basic rondel morphology.

Mulholland (1993) and Mulholland and Rapp (1992) define a rondel as a short cylinder to truncated or bevelled cone with a base outline that is approximately circular to oval or other curved shaped (concave) and the top is a flat to slightly concave or convex face or has elevated ridges. They define three types of rondels: entire (edges of the base are all convex), flattened (some edges of the base are straight), and indented (some edges of the base are concave) (Mulholland, 1993; Mulholland and Rapp, 1992). Mulholland (1989) and Mulholland and Rapp (1992) describe three types of morphological features, which are applicable to the three types of rondels described above: tabular (top and base are of the same size and shape), plateau (the top is smaller or of different shape than the base, or both), and ridge (the top has one or more ridges that slope to the base). Based on these descriptions, Mulholland and Rapp (1992) illustrate the variations of rondels in a taxanomic key.

Fredlund and Tieszen (1994) refer to rondels as conical (circular to oval in abaxial/adaxial outline, exhibiting a distinctly asymmetrical cross-section), keeled (distinguished from the conical type by the crested, rather than pointed, flat or concave top, also referred to as the adaxial surface), or pyramidal (characterized by a rectangular abaxial/adaxial outline, and assummetrical or trapezoidal cross-section) phytoliths. Blinnikov (2005) has similar descriptions of rondels, which he based on Bozarth (1993a), Fredlund and Tieszen (1994), Piperno (1988), and Twiss et al.'s (1969), earlier work. He refers to four types of rondel: oval and elongated rondel, rounded and keeled rondel, rounded and horned rondel, and pyramidal rondel.

Staller and Thompson (2002) have described rondels as circular to oval in outline when viewed from above. They also described them as short cylinders when viewed as three-dimensional shapes (Staller and Thompson, 2002). In three-dimensional morphology, the shape of the faces (thick and thin faces) of the cylinder, are also described. The smaller face of the rondel, which appears more robust, is described as the thick face, it can be defined as entire or notched, and the number of notches can be counted. The opposite face, which is not as robust, is described as the thin face, which may also be entire, or indented, and the number of indentations can be counted. Based on these descriptions, Staller and Thompson (2002) therefore refer to rondels as being entire or indented bases based on the shape of the thin face, and notched or unnotched, based on the shape of the thick face.

Based on Mulholland and Rapp's (1992) classification system, Thompson (see Hart et al., 2003) further developed his descriptive terms to derive a taxonomic key for rondels. In Hart et al. (2003), Thompson classifies rondels according to planar view of their faces. This system takes into consideration the shapes of the face, if there are decorations present on the faces, if the face is thin or thick, the relation between the two faces, if the face is entire or indented, the number of indentations and where they are placed (Hart et al., 2003). However, this system can be a bit difficult to follow, since it does not show clearly what combination of features can be encountered.

Lu and Liu (2003) also look at the different types of rondels. They refer to the rondels as being oval to circular in shape in a category of their own, or put them into another category called rondel/saddle ellipsoids, other types of rondels are referred to as flat towers, two horned towers and spool/horned towers. Lu and Lui (2003) acknowledge that most researchers should try to avoid the use of different descriptive terms for the description of rondel types. However, they do make the point that no uniform or standard terminology has been adopted in the literature. They even suggest that these types of phytoliths warrant further investigations since they are likely to be of precise taxonomic value.

Piperno (2006) mentions that the utility of size characteristics of rondels, has yet not been sufficiently examined. Of course, square cord distances, which takes account of length, width and aspect ratio (length/width) of the interior surface of each phytolith (Hart et al., 2003, 2007; Thompson and Mulholland, 1994; Thompson et al., 2004) and cluster analysis using Unweighted Pair Group Method with Arithmetic Mean linkage with squared chord distances (Hart et al., 2007) have also been applied, often in combination with morphology, to the study of rondels. The statistical methods mentioned above have been used as an identification technique to differentiate both maize and wild rice rondels in carbonized food residues and from other plants (Hart et al., 2003, 2007; Thompson and Mulholland, 1994; Thompson et al., 2004). Thompson et al. (2004) use squared chord distance values for shape and size data to differentiate maize from other grasses; however only a few wild grasses that would have potentially been consumed were analyzed in this study. This is fine if you are trying to differentiate a few species that have very different phytolith assemblages, but one should consider the possibility of other grasses being consumed or at least contamination of the residue by adding of ashes for seasoning, or from the soil after burial.

Maize cobs are also known to produce diagnostic rondel phytoliths that have been identified at prehistoric sites in the Great Plains (Mulholland, 1989, 1993; Bozarth and Guderjan, 2004). Rondels are the dominant phytolith produced in maize cupules and the soft and hard glumes of the cobs (Pearsall et al., 2003; Pearsall et al., 2004b; Piperno and Pearsall, 1993b). Rondels first received attention in the late 80's and early 90's (Bozarth, 1993a; Mulholland, 1989, 1993, Piperno and Pearsall, 1993) as being representative of maize cob assemblages. However, Bozarth (1993a) was the first to describe a type diagnostic of maize.

In her analysis of North Dakota grasses, Mulholland (1989) found that even though most rondels are produced in the leaf blade and inflorescence of Pooideae grass subfamily, they are also present in the leaf blade and inflorescence of other grass subfamilies such as Arundinoideae, Chloridoideae and Panicoideae. Mulholland's (1989) data showed that rondels produced in maize (*Zea mays*), were higher in frequency than in other grasses. She noted that cob shafts produced a rondel phytolith that might be an indicator of maize based on a combination of two morphological characteristics: a plateau top and a base with multiple indentations (Mulholland, 1989, 1993). She argued that even if plateau tops were common in rondels from wild grasses and many species had indented bases, few species found to date produced significant amounts of rondels with both characteristics (Mulholland, 1993). Piperno (2006) refers to these multiple indentations as "prominent finger-like projections" or indentations numbering from three to four that can be seen on one of the face of the rondel, which occur infrequently in non-*Zea* species. Piperno (1984) and Mulholland (1993) noticed that, overall, long shapes, such as sinuates, rectangles and dumbbells are usually found in the leaf blade and that saddles and rondels are more abundant in the cob chaff and occur in more grass species.

Within cultural sediments from Big Hidatsa, North Dakota, Mulholland (1993) noted the presence of rondels in large quantities (up to 9.1%). Due to the rarity of crosses at this site, and the possibility that the dumbbells originated from various wild grasses, she concluded that maize leaf and husk did not contribute much to the samples (Mulholland, 1993). Since rondels with multiple indented sides and plateau tops are produced in maize in large amounts, even though they are not diagnostic of maize since they are produced in small quantities in some wild grasses such as *Stipa viridula*, it was concluded that samples such as hearths containing large amounts of these phytoliths could be used as an indicator of maize (Mulholland, 1993). This conclusion seems to make sense in light of more recent literature in combination with ethnohistorical records.

Bozarth (1993a) found that wavy-top phytoliths (Figure 12) could be used to identify maize in soil samples at a Great Bend Aspect village site in Central Kansas. He concluded that the rondels found in maize cobs were diagnostic of the plant, which was based on his comparative analysis of cob phytoliths with other cultigens, grasses, and published taxonomic classifications of phytoliths found in wild grass species common to central North America. In four varieties of maize, Bozarth (1993a) observed the following characteristics: top and bottom are non-sinuous, top is shorter than bottom, bottom has rounded ends (when looking at it from the top or bottom view); flat bottom, top flat or wavy, sides concave, top and bottom same length or top longer than bottom (when looking from the side view). He reported that no species in the Arundinoideae, Chloridoideae, Oryzoideae, and Panicoideae subfamilies produced similar phytoliths. Bozarth (1993a) noticed that some species shared at least one or more feature, but not all, with this type of phytolith, such as *Agropyron smithii* that produces rondels that are non-sinuous with round ends. Due to the absence of maize cob phytoliths types in his control samples and only finding maize cob type phytoliths from cultural features in two of the six sites in the area, Bozarth (1993a) concluded that the native flora did not produce these types of

5.3.3. The Usefulness of Starch Analysis in Archaeological Contexts

The study of starch grains at archaeological sites is very important since starchy foods were often added to soups or stews, as a thickening agent (Wissler, 1986). Many domestic plants also tend to have high starch content. Starch grains have been used to identify plant species such as maize from soils, sediments, stone tools and carbonized food residues (Babot and Apella, 2003; Boyd et al., 2006, 2008; Hall et al., 1989; Haslam, 2004; Iriarte et al., 2004; Lentfer et al., 2002; Loy, 1994; Parr and Carter, 2003; Pearsall et al., 2004b; Perry, 2004; Piperno and Holst, 1998; Surette, 2005; Torrence et al., 2004; Zarrillo and Kooyman, 2006). Starch grains have been employed successfully in archaeological research to reconstruct tool use, subsistence patterns, techniques of food preparation, and patterns of land use (Lentfer et al., 2002; Pearsall et al., 2004b; Torrence et al., 2004). Some species, such as tubers, do not carbonize well, produce very few phytoliths and pollen grains, and therefore starch can be the only paleodiet indicator for these plants (Piperno and Holst, 1998). This could be the case for common beans (*Phaseolus vulgaris*) where if only the seeds are eaten, no phytoliths from the pods will be identifiable, therefore only the starch from the seed remains. Examples of this can be found in Iriarte et al. (2004) and Boyd et al.'s (2006, 2008) studies, where starch grains that look like beans (*Phaseolus vulgaris*) were found where no phytoliths of this plant were present.

Pearsall et al. (2004b) argued that if phytoliths had been the only focus of their research, maize processing would have been underestimated by more than 50% (since many fewer phytoliths were recovered than starch grains). It is believed that the difference in abundance between starch grains and phytoliths is due to the differential deposition of maize plant tissue in the processing context, and to the differential survival of cob phytoliths and starch grains in sediments due to simple weight of numbers (Haslam, 2004; Pearsall, 2004b).

Extraction of starch grains from residues and soils or sediment often follows procedures that are used for phytolith extraction from samples, allowing for the extraction of multiple types of microfossils (Boyd et al., 2006; Parr and Carter, 2003). When looking at groundstones gentle brushing (Babot and Apella, 2003) or sonic extraction (Perry, 2004) is used since they are less likely to harm the archaeological residues. During preparation of starch residue samples, one must avoid using powdered rubber gloves which usually contain starch and to avoid the risk of gelatinisation of fossil starch grains, one must not use hot (> 40°C) solutions or instruments (Horrocks, 2005).

Starch grains can be subject to attrition, and it is necessary to understand starch decomposition processes to accurately reconstruct archaeological activities involving starchy plants (Haslam, 2004). Various, complex factors, can affect starch survival including enzymes, clays, metals, soil properties, fungi, bacteria, the size of the grain, the amylose content, whether the artefact was sheltered, buried or exposed on the surface, as well as location of the starch granules on the artifacts (Haslam, 2004). Food preparation methods may also have an impact on the recovery of starch grains on artefacts (Hart et al., 2007). Based on their cooking experiments, Hart et al. (2007) noticed that there was a potential loss of starches as a result of frothing and boiling over of the food in the pot.

5.4. SUMMARY

Phytoliths can be good indicators of past diets and environments; however much work is still needed. Due to the added complications that the same types of phytoliths can be found in multiple species, and that some plant species produce multiple types of phytoliths, one must look for types that are species specific (Barboni et al., 1999; Brown, 1984; Mulholland, 1989; Strömberg, 2004). The environment can change the size of phytoliths in plants; however the morphology of phytoliths do not seem to be affected by this since the production of phyotliths is characterized by genetic rather than environmental control (Ball and Brotherson, 1992).

Techniques such as squared-chord distance measurements of rondel phytoltihs may be subject to bias where size is an issue, and most researchers have only thus far taken in account a few grass species that might have been consumed when applying this technique (Hart et al., 2003; Thompson et al., 1994). It is also highly dependent on regional flora used for comparison. The seeds in the inflorescence of various grasses can be turned into flour; the grasses themselves can be used as a fuel in fires or ashes as a seasoning; and the artefacts can be contaminated after burial. Therefore there are many ways phytoliths of wild grasses can make their way into carbonized food residues, either naturally or intentionally.

Furthermore, there is no standard classification of rondel types (Lu and Liu, 2003). This makes identification and the use of such taxonomies quite difficult, especially since various terms are used, as well as some people refer to the top as the base or vice versa. This is why it is important for a new classification to come to light that spans the total variation of rondel phytoliths with simpler descriptive terms that are easy to follow. The classification developed as part of this project has also an added importance since it deals with the regional flora from the Lake of the Woods and surrounding area; an "imported" taxonomy would probably not be appropriate.

Thus far, a diagnostic type of rondel phytoliths has been clearly identified for maize (*Zea mays*) (Bozarth, 1993a; Pearsall et al., 2003). The wavy-top rondel type, which is only found in maize cobs, has been used to detect the presence of the plant for a number of years, and recently, as far north as southern Manitoba (Boyd et al., 2006, 2008; Surette, 2005). Compared to maize, no diagnostic types or rondel phytoliths for wild rice have been clearly identified. The rondels of wild rice have been examined in various studies (Hart et al., 2003; Terrell and Wergin, 1981; Thompson et al., 1994); however, no types have been identified as being particular to the plant. Various wild plants, including wild rice have been compared with maize to determine the validity of the types found in the cobs, although an equal study has not been conducted for wild rice.

There is limited work done on starch grain analysis in North America. Even though starch from maize, common beans, and wild rice has been described, and some diagnostic types have been clearly identified, they have not been properly compared to the suite of wild edible species in the study area. Therefore, the full potential of ancient starch analysis for the study area cannot be fully realized until proper comparative collections and comprehensive identification key have been established. Historically, many starchy plants were being used by many native groups; however, their economic potential is greatly underestimated especially for prehistoric cultures. Edible parts of some potentially economic plants used by prehistoric people do not carbonize in hearths, preserve well in soils or carry any phytoliths. Therefore, starch grains analysis might be the only proxy available to identify such plants.

PART 2: PHYTOLITH ANALYSIS OF COMPARATIVE PLANT MATERIALS, SEDIMENT, AND CARBONIZED FOOD RESIUDES

CHAPTER 6. METHODS AND MATERIALS

6.1. INTRODUCTION

This chapter reviews the methods used for the different components of the research presented in this thesis. Criteria and techniques used for the selection, extraction, and classification of phytoliths and/or starch granules of the comparative plant materials, lake sediment, and carbonized food residues are also described.

6.2. COMPARATIVE PLANT SAMPLES

Comparative plant materials were collected from the Thunder Bay and Lake of the Woods area. Some samples were also made available from the Lakehead University Herbarium. Plants collected include grasses, sedges, aquatic plants and traditional economic plants used by Aboriginal Peoples in the area during the historic period. Grass species were chosen based on their presence in Northwestern Ontario as documented by the Lakehead University Herbarium database, also they had to be native to the area (Looman and Best, 1987; Newmaster et al., 1997), and thrive in, by, or near, aquatic environments. Parts of the leaves, stems, inflorescences, tubers, rhizomes, fruits, seeds, and flowers were collected from 61 plants for phytolith and starch comparisons (Appendix A); however, the focus of this thesis was mainly on the phytoliths.

The method used for extracting phytoliths from the comparative plant materials followed standards devised by Staller and Thompson (2002) and Hart et al. (2003) for extracting microfossils from carbonized food residues. Plant samples prepared for phytolith extraction were processed in heated nitric acid (50%) for 24 hours and then washed in water and centrifuged at 3000 rpm for 15 minutes; this last step was repeated 5 times. Once the samples were washed, they were screened in a clean 250 µm sieve to filter out any remaining plant materials that was not dissolved by the nitric acid. The comparative samples were mounted in Entellen and analyzed using a compound microscope under cross-polarized light (XPL) and differential interference contrast (DIC).

In total, a minimum of 300 rondel phytoliths were counted from each grass species, while other species were only examined for the presence/absence of "confuser" types (phytoliths that might have one or more features similar to a rondel). Multiple samples of *Zizania palustris* were examined for variations of rondel types within the same plant. Rondel types were classified based on a combination of morphological features (see Appendix B); the shape of the top (flat, spiked, wavy), sides (straight, convex, concave) and base (entire, indented, concave) including height (Short = rondel is wider than it is tall, Tall = rondel is taller than it is wide). Although size can be used in the identification of phytoliths, it was thought prudent to stick to morphological features only.

Since starch identification was not the major focus of this thesis, only a few species were chosen for comparison (see Appendix A). Economically valuable plants used by native communities during the historic period chosen for this analysis, among others, include: yellow pond lilies (*Nuphar variegatum*), common beans (*Phaseolus vulgaris*), prairie breadroot (*Psoralea esculenta*), broad-leaved arrowheads (*Sagittaria latifolia*), cattails (*Typha latifolia*), maize (*Zea mays*), and wild rice (*Zizania aquatica* and *Zizania palustris*) (Moerman, 1998; Newmaster et al., 1997; Peterson, 1977).

Collected samples of comparative starch granules allowed for a tentative identification only of starch grains for species not found in the literature. Starch samples were also collected from key economic species in order to determine if they produce similar types to the ones described as being diagnostic of maize (*Zea mays*) and common beans (*Phaseolus vulgaris*).

However, additional comparative starch samples of economically important starchy plants should be analysed to give more secure identifications.

Comparative starch grains were extracted using different methods depending on the part of the plant sampled. Seeds were crushed using a clean pestle and mortar, and fruits or fibrous materials such as tubers or rhizomes were chopped and then crushed like the seeds to remove the starch from these materials. Water was usually added to these materials during the crushing to help with the extraction of the starch, and to minimize dust from the starch contaminating the lab. The material in the mortar was filtered in a 250 µm sieve to remove any unwanted organic materials which was poured in a 50 mL centrifuge tube. The remaining material was then centrifuged at 3000 rpm for 15 minutes, the supernatant was removed with new disposable pipettes and the remaining material was poured in a microcentrifuge tube in reagant alcohol, and then mounted onto slides. The starch grains were examined and photographed using a compound microscope equipped with XPL and DIC.

In order to make sense of the data that was collected, a cluster analysis program called Hierarchical Clustering Explorer was used (Seo, 2008). The purpose of using a cluster analysis program has one key goal: the grouping or segmenting of the samples into subsets or clusters in order to show the relation between the samples that are closely related to one another and the ones that are not (Manning et al., 2008). Hierarchical agglomerative clustering is presented in a diagram known as a dendrogram; this illustrates the fusions or divisions made at each successive stage of analysis (Lorr, 1983; Manning et al., 2008). Four types of hierarchical agglomerative clustering algorithms can be applied in order to define distance or similarity between clusters, they are known as single linkage clustering, complete linkage clustering, average linkage clustering, and average group linkage clustering (Manning et al., 2008). Single linkage clustering merges a pair of samples based on their two most similar elements, while complete linkage clustering merges a pair of samples based on their most dissimilar elements, and average and average group linkages is based on all similarities between samples (Manning et al., 2008). Because there is a lot of redundancy in rondel phytolith types from one plant to another, with only certain types occurring in one or very few plants, the best linkage method that illustrates which plants are most similar based on rondel types should be used.

6.3 LAKE SEDIMENTS

Lake sediment sampling for this project was done in July of 2006. The criteria used to determine which lake to core dependent primarily on two variables; small size and catchment, and having the historical existence of wild rice within the lake. A universal corer was used for sediment sampling on the side of a canoe in Lulu Lake (Rice Bay), near the town of Kenora (Figure 20).

When the samples were collected, wild rice was growing across the bay; some plants were still at their floating stage, while others were actually growing out of the water, of which, a few were pollinating. Although the core was not dated, the sediment samples are assumed to have been deposited recently, either historically or shortly before. Because a modern distribution of wild rice was present in the lake, it was hypothesized that phytoliths representative of the plant would be found in the sediment.

There were a few rivers around the lake, although the bay was quite sheltered from these, therefore it seemed that contamination from other sources seemed unlikely. However, many cottages are located around the lake and contamination is possible, especially in causing high growths of algae in the lake, thus increasing the diatom content, which waters down the phytolith population in samples.

The core was a massive (structureless) sapropel (Figure 21) , its total length measured 72 cm, and was taken in approximately 1.5 m of water; the core was sub-sampled on the shore at 2 cm intervals, using a core extruding apparatus, that were placed in individual sample bags.

certain crystalline properties (Hall et al., 1989). The semi-crystalline birefringence property of the starch grain is produced by the orientation of the two polysaccharides (amylose and amylopectin), which appears as a distinct extinction cross when viewed under cross-polarized light (Calvert, 1997).

Two main forms of starch grains produced in plants are important for archaeological analysis: transitory starch and storage starch (Haslam, 2004). Transitory starch is produced in chloroplasts at the locations of photosynthesis (leaves and green stems). They can be very small (between 3 – 10 μm in diameter) and are often not distinguished or counted when starch is used in archaeological investigations (Haslam, 2004). Storage starch is produced in the amyloplasts of major storage organs such as seeds, roots, tubers, corms, fruits and rhizomes (Haslam, 2004; Piperno and Holst, 1998) with amylopectin forming most of its composition (70-80%) (Haslam, 2004). They serve as long-term storage, as a source of food for the plant during unfavorable conditions, and a carbon source during germination (Haslam, 2004).

Starch grains are variable in size (1-200 μm), shape (spherical or oval) and form (single, compound to semi-compound grain). The position of the hilium can be centric or eccentric, and its (i.e. the hilium) shape may be rounded, lobed, forked or stellate. Single grains are grains that are not found to exhibit signs of being in a cluster, whereas compound grains are grains that are clustered together exhibiting each their own distinct birefringence. Compound grains that escaped from the starch cluster exhibit a curved surface, and one or more pressure facets. Semi-compound grains are different from compound grains since they are aggregates (more than one grain clustered together with layers around them) displaying only one polarized cross (Hall et al., 1989).

Very often starch grains are used as an additional proxy for the identification of plants since they are often found with other microfossils such as phytoliths (Boyd et al., 2006; Parr and Carter, 2003). Most starches can be identified to species with the help of various identification keys and if the comparative collection of the researcher has all the necessary plant materials from the area of interest (Lentfer et al., 2002; Perry, 2004; Torrence et al., 2004). Comparative starch samples can be simply prepared by crushing or grinding samples (after they have been washed of any contaminants) in clean water, filtering them (Piperno and Host, 1998), and then transferred onto a microscope slide in a mounting medium (Surette, 2005; Zarrillo and Kooyman, 2006).

Starch grains are identified based on their size, shape, visibility, presence or absence of lamellae, location of the hilium, presence or absence of internal fissuring, and birefringence (displays a clear “Maltese” or extinction cross with distinctive characteristics under cross-polarized light) (Babot and Apella, 2003; Güler et al., 2002; Haslam, 2004; Hoover and Ratnayake, 2002; Pearsall et al, 2004b; Perry, 2004; Su et al., 1998; Torrence et al., 2004). Like phytoliths, the three-dimensional morphology of starch grains is also important for identification (Perry, 2004). For the identification of starch grains, as with phytoliths, it is noted that it is important to use multiple criteria for a positive identification (Torrence et al, 2004).

Various shapes of starch grains exist that allow for identification, including polygonal, elliptical, oval or ovoid, domed, cap-shaped or truncated, among many others, as well as the shape of the outline of the grain (round, mixed round, angular) (Lenfter et al., 2002; Torrence et al., 2004). Torrence et al. (2004) built a key as part of their study and identified 242 different starch grain shapes. Like phytoliths, they found that morphological traits of some grains can overlap between species, and that not all starch grains are useful for identification. Therefore, positive identification of species was based on types that occurred only in one species and had a unique morphology. They also insisted that in the case where a unique morphology is not available, one should consider the population as a whole, rather than identifying individual granules.

Multiple techniques can be used to identify starch residues. These methods include optical microscopy (Perry, 2004), X-ray diffraction (XRD) (Güler et al., 2002), and scanning electron microscopy (SEM) (Babot and Apella, 2003). Iodine staining is another method used to identify starch grains, especially when they are gelatinized or damaged (Babot and Apella, 2003; Hall et al., 1989; Haslam, 2004). The temperature of gelatinization can also be used as an identification tool for starch grains (Hall et al., 1989). New methods such as laser differential interference contrast microscopy have also been applied to starch grain identification (Li et al., 2006). In their study, Li et al. (2006) used this method to look at the growth ring patterns from the starches of potato and maize, and found that the density of rings was different for each sample at the same length of radius.

There is often a bias in archaeological studies towards the starch produced in storage organs because of the diagnostic potential of larger grains, and because there is often an overlap in size (grains measuring between 1-5 µm) between storage grains and transitory grains (Haslam, 2004). To alleviate this problem, new research has looked at the potential of iodine staining techniques to differentiate between starches grains derived from transitory versus storage contexts (Haslam, 2004).

Starch swells in water but upon drying it returns to its orginal shape, providing that the swelling was not too severe and that the temperature was not too high (Haslam, 2004). If the temperature is too high (usually above 60 °C), the starch grains undergo irreversible, pronounced swelling, lose their extinction crosses and granular features, and can be difficult to identify without chemical treatment. This process is called gelatinisation (Haslam, 2004). In the absence of water, starch is destroyed, since it does not carbonize (Haslam, 2004).

5.3.2. The Starch of Maize, Common Beans, and Wild Rice

Characteristics of starch grains produced in the kernels of maize are described by Pearsall et al. (2004b). These authors examined nine varieties of maize, and consulted the existing literature (Pearsall et al, 2004b). When examined under plane polarized light maize starch grains

(Figure 17) are described as varying in shape from spherical to oval-spherical to polyhedral (depending on how tightly packed granules were in the kernel) and can also be hemispherical or vase-shaped (Pearsall et al., 2004b). A linear Y or X fissure is often formed in the center of the grain due to drying (Pearsall et al., 2004b).

For example, the size of maize starch grains range from 4 to 24 μm and are larger than those produced by most wild grasses, and where size overlaps, wild grass starch grains usually have distinctive morphologies that are different from *Zea* (Babot and Apella, 2003; Pearsall et al., 2004b). Under cross-polarized light, symmetrical extinction crosses are visible within the maize starch grains exhibiting a nearly perfect 90° angle (Babot and Apella, 2003; Pearsall et al., 2004b).

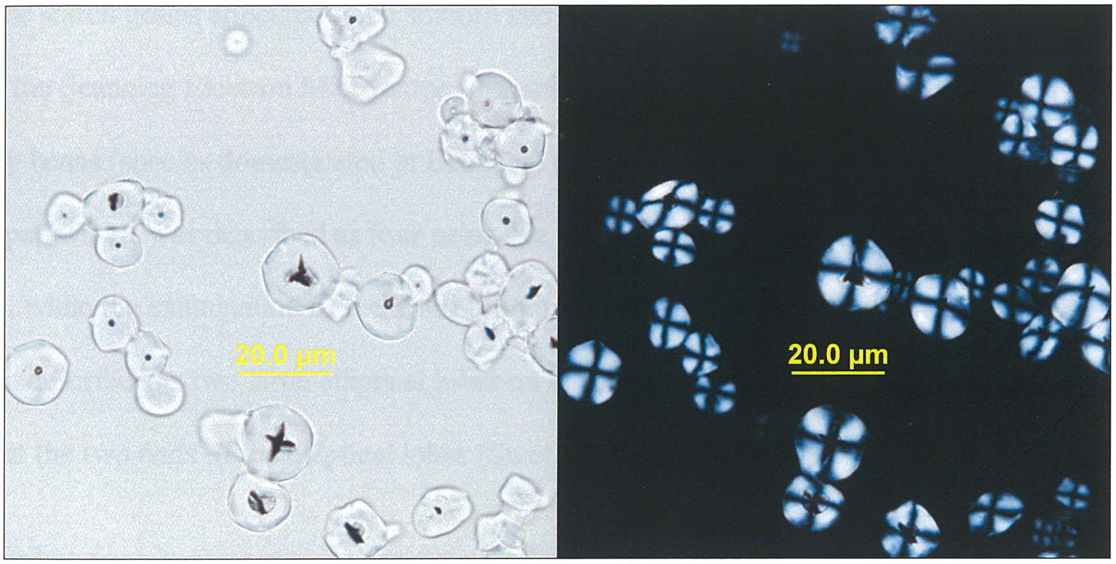

Figure 17. Photomicrographs of starch granules from "Mandan corn" (*Zea mays*) showing X and Y fissuring: plane polarized light (PPL) (left), cross-polarized light (XPL) (right).

Examination of the structures of bean (*Phaseolus* sp.) starch has been undertaken by various researchers (Hoover and Ratnayake, 2002; Hsieh et al., 1999; Piperno and Holst, 1998; Su et al., 2002). Microscopic examination of black, pinto, and navy bean (*Phaseolus vulgaris*) by Hoover and Ratnayake (2002) revealed that the shapes (round, irregular, elliptical, oval) of the starch grains of the plants are similar (Figure 18). It was observed that pinto bean starches showed the highest variation (length and width) in size distribution (Hoover and Ratnayake, 2002).

Su et al. (1998) looked at six varieties of beans, out of which four were common beans (*Phaseolus vulgaris*): Great Northern bean, Navy bean, Red Kidney bean and Pinto bean. Great Northern bean has a width range of 21 to 30 μm and a length range of 25 to 38 μm and Navy bean had a width range of 16 to 26 μm and a length range of 17 to 30 μm. Red Kidney bean had a width range of 21 to 29 μm and a length range of 22 to 35 μm and Pinto bean had a width range of 20 to 24 μm and a length range of 20 to 27 μm (Su et al., 1998). Sizes and shapes of Great Northern, Red Kidney and Pinto beans were reported as being similar (Sue et al., 1998).

It was noted both by Su et al. (1998) and Hoover and Ratnayake (2002) that the surfaces of these starch grains appeared to be smooth and showed no evidence of fissures when observed under the Scanning Electron Microscope. Examination of the Navy, Great Northern and Red Kidney beans (species domesticated in Ecuador) under cross-polarized light revealed a particular cross pattern. It was described as four petal-like lobes/segments around a small dark cross in the center, while the examination of the Pinto bean under cross-polarized light revealed a cross pattern described as two large elliptical lobes on either side of the cross with two small round lobes at the two ends of the elliptical lobes (Su et al., 1998).

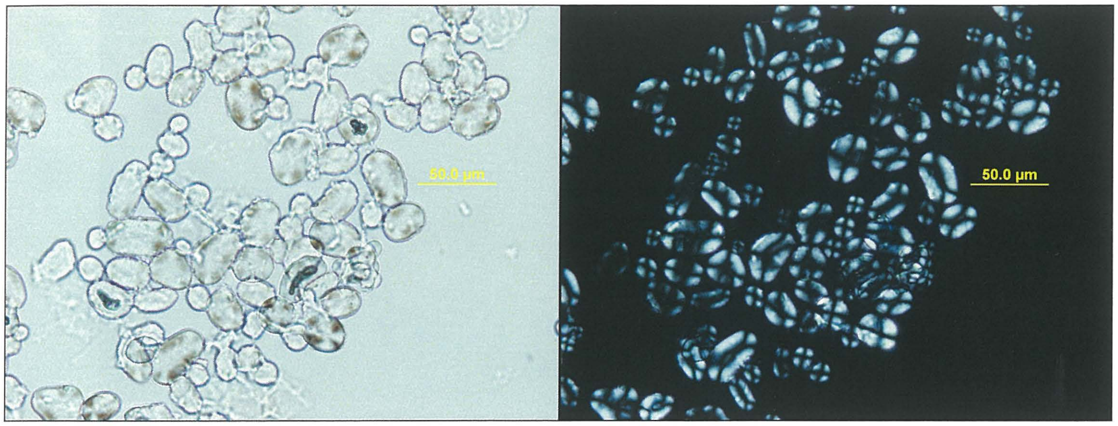

Figure 18. Photomicrographs of starch granules from red kidney beans (*Phaseolus vulgaris*): plane polarized light (left), cross-polarized light (XPL) (right).

The starch granules of wild rice (*Zizania aquatica*) (Figure 19) are smaller in size (2 – 7 µm) than granules of wheat starch or any other common cereal starches, except perhaps for regular white rice starch, and they are angular and polygonal in size (Lorenz, 1981). Gelatinization of wild rice (*Z. aquatica*) occurs at a higher temperature than that of wheat starch, but similar to that of regular white rice (Lorenz, 1981). At 63˚C gelatinization of wild rice starch is in its initial stages with 2% of granules gelatinized, at 67˚C, the starch is in its midpoint stage with 50% of granules gelatinized, and at 73˚C the starch is at its endpoint stage with 98% of granules gelatinized (Lorenz, 1981). Lorenz (1981) mentions that even though wild rice starch showed a high viscosity at 92˚C, the intermolecular forces in the granules seemed to be weak since a slight breakdown occurred on further cooking and that on cooling there is little "set-back" because of the small amount of amylose content (about 2%) in wild rice starch.

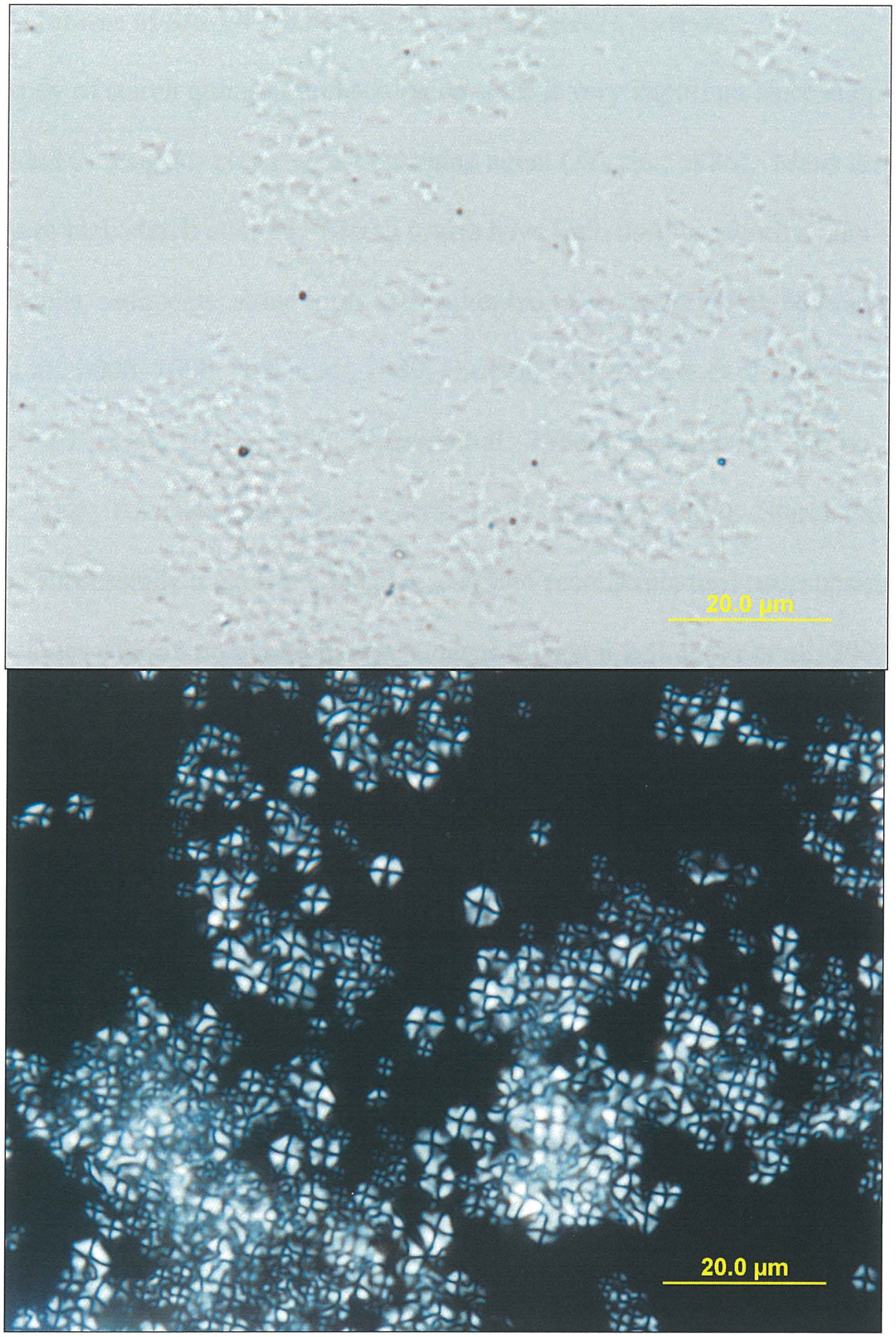

Figure 19. Photomicrograph of starch granules from wild rice (*Zizania palustris*): plane polarized light (top), cross-polarized light (XPL) (bottom).

5.3.3. The Usefulness of Starch Analysis in Archaeological Contexts

The study of starch grains at archaeological sites is very important since starchy foods were often added to soups or stews, as a thickening agent (Wissler, 1986). Many domestic plants also tend to have high starch content. Starch grains have been used to identify plant species such as maize from soils, sediments, stone tools and carbonized food residues (Babot and Apella, 2003; Boyd et al., 2006, 2008; Hall et al., 1989; Haslam, 2004; Iriarte et al., 2004; Lentfer et al., 2002; Loy, 1994; Parr and Carter, 2003; Pearsall et al., 2004b; Perry, 2004; Piperno and Holst, 1998; Surette, 2005; Torrence et al., 2004; Zarrillo and Kooyman, 2006). Starch grains have been employed successfully in archaeological research to reconstruct tool use, subsistence patterns, techniques of food preparation, and patterns of land use (Lentfer et al., 2002; Pearsall et al., 2004b; Torrence et al., 2004). Some species, such as tubers, do not carbonize well, produce very few phytoliths and pollen grains, and therefore starch can be the only paleodiet indicator for these plants (Piperno and Holst, 1998). This could be the case for common beans (*Phaseolus vulgaris*) where if only the seeds are eaten, no phytoliths from the pods will be identifiable, therefore only the starch from the seed remains. Examples of this can be found in Iriarte et al. (2004) and Boyd et al.'s (2006, 2008) studies, where starch grains that look like beans (*Phaseolus vulgaris*) were found where no phytoliths of this plant were present.

Pearsall et al. (2004b) argued that if phytoliths had been the only focus of their research, maize processing would have been underestimated by more than 50% (since many fewer phytoliths were recovered than starch grains). It is believed that the difference in abundance between starch grains and phytoliths is due to the differential deposition of maize plant tissue in the processing context, and to the differential survival of cob phytoliths and starch grains in sediments due to simple weight of numbers (Haslam, 2004; Pearsall, 2004b).

Extraction of starch grains from residues and soils or sediment often follows procedures that are used for phytolith extraction from samples, allowing for the extraction of multiple types of microfossils (Boyd et al., 2006; Parr and Carter, 2003). When looking at groundstones gentle brushing (Babot and Apella, 2003) or sonic extraction (Perry, 2004) is used since they are less likely to harm the archaeological residues. During preparation of starch residue samples, one must avoid using powdered rubber gloves which usually contain starch and to avoid the risk of gelatinisation of fossil starch grains, one must not use hot (> 40°C) solutions or instruments (Horrocks, 2005).

Starch grains can be subject to attrition, and it is necessary to understand starch decomposition processes to accurately reconstruct archaeological activities involving starchy plants (Haslam, 2004). Various, complex factors, can affect starch survival including enzymes, clays, metals, soil properties, fungi, bacteria, the size of the grain, the amylose content, whether the artefact was sheltered, buried or exposed on the surface, as well as location of the starch granules on the artifacts (Haslam, 2004). Food preparation methods may also have an impact on the recovery of starch grains on artefacts (Hart et al., 2007). Based on their cooking experiments, Hart et al. (2007) noticed that there was a potential loss of starches as a result of frothing and boiling over of the food in the pot.

5.4. SUMMARY

Phytoliths can be good indicators of past diets and environments; however much work is still needed. Due to the added complications that the same types of phytoliths can be found in multiple species, and that some plant species produce multiple types of phytoliths, one must look for types that are species specific (Barboni et al., 1999; Brown, 1984; Mulholland, 1989; Strömberg, 2004). The environment can change the size of phytoliths in plants; however the morphology of phytoliths do not seem to be affected by this since the production of phyotliths is characterized by genetic rather than environmental control (Ball and Brotherson, 1992).

Techniques such as squared-chord distance measurements of rondel phytoltihs may be subject to bias where size is an issue, and most researchers have only thus far taken in account a few grass species that might have been consumed when applying this technique (Hart et al., 2003; Thompson et al., 1994). It is also highly dependent on regional flora used for comparison. The seeds in the inflorescence of various grasses can be turned into flour; the grasses themselves can be used as a fuel in fires or ashes as a seasoning; and the artefacts can be contaminated after burial. Therefore there are many ways phytoliths of wild grasses can make their way into carbonized food residues, either naturally or intentionally.

Furthermore, there is no standard classification of rondel types (Lu and Liu, 2003). This makes identification and the use of such taxonomies quite difficult, especially since various terms are used, as well as some people refer to the top as the base or vice versa. This is why it is important for a new classification to come to light that spans the total variation of rondel phytoliths with simpler descriptive terms that are easy to follow. The classification developed as part of this project has also an added importance since it deals with the regional flora from the Lake of the Woods and surrounding area; an "imported" taxonomy would probably not be appropriate.

Thus far, a diagnostic type of rondel phytoliths has been clearly identified for maize (*Zea mays*) (Bozarth, 1993a; Pearsall et al., 2003). The wavy-top rondel type, which is only found in maize cobs, has been used to detect the presence of the plant for a number of years, and recently, as far north as southern Manitoba (Boyd et al., 2006, 2008; Surette, 2005). Compared to maize, no diagnostic types or rondel phytoliths for wild rice have been clearly identified. The rondels of wild rice have been examined in various studies (Hart et al., 2003; Terrell and Wergin, 1981; Thompson et al., 1994); however, no types have been identified as being particular to the plant. Various wild plants, including wild rice have been compared with maize to determine the validity of the types found in the cobs, although an equal study has not been conducted for wild rice.

There is limited work done on starch grain analysis in North America. Even though starch from maize, common beans, and wild rice has been described, and some diagnostic types have been clearly identified, they have not been properly compared to the suite of wild edible species in the study area. Therefore, the full potential of ancient starch analysis for the study area cannot be fully realized until proper comparative collections and comprehensive identification key have been established. Historically, many starchy plants were being used by many native groups; however, their economic potential is greatly underestimated especially for prehistoric cultures. Edible parts of some potentially economic plants used by prehistoric people do not carbonize in hearths, preserve well in soils or carry any phytoliths. Therefore, starch grains analysis might be the only proxy available to identify such plants.

PART 2: PHYTOLITH ANALYSIS OF COMPARATIVE PLANT MATERIALS, SEDIMENT, AND CARBONIZED FOOD RESIUDES

CHAPTER 6. METHODS AND MATERIALS

6.1. INTRODUCTION

This chapter reviews the methods used for the different components of the research presented in this thesis. Criteria and techniques used for the selection, extraction, and classification of phytoliths and/or starch granules of the comparative plant materials, lake sediment, and carbonized food residues are also described.

6.2. COMPARATIVE PLANT SAMPLES

Comparative plant materials were collected from the Thunder Bay and Lake of the Woods area. Some samples were also made available from the Lakehead University Herbarium. Plants collected include grasses, sedges, aquatic plants and traditional economic plants used by Aboriginal Peoples in the area during the historic period. Grass species were chosen based on their presence in Northwestern Ontario as documented by the Lakehead University Herbarium database, also they had to be native to the area (Looman and Best, 1987; Newmaster et al., 1997), and thrive in, by, or near, aquatic environments. Parts of the leaves, stems, inflorescences, tubers, rhizomes, fruits, seeds, and flowers were collected from 61 plants for phytolith and starch comparisons (Appendix A); however, the focus of this thesis was mainly on the phytoliths.

The method used for extracting phytoliths from the comparative plant materials followed standards devised by Staller and Thompson (2002) and Hart et al. (2003) for extracting microfossils from carbonized food residues. Plant samples prepared for phytolith extraction were processed in heated nitric acid (50%) for 24 hours and then washed in water and centrifuged at 3000 rpm for 15 minutes; this last step was repeated 5 times. Once the samples were washed, they were screened in a clean 250 μm sieve to filter out any remaining plant materials that was not dissolved by the nitric acid. The comparative samples were mounted in Entellen and analyzed using a compound microscope under cross-polarized light (XPL) and differential interference contrast (DIC).

In total, a minimum of 300 rondel phytoliths were counted from each grass species, while other species were only examined for the presence/absence of "confuser" types (phytoliths that might have one or more features similar to a rondel). Multiple samples of *Zizania palustris* were examined for variations of rondel types within the same plant. Rondel types were classified based on a combination of morphological features (see Appendix B); the shape of the top (flat, spiked, wavy), sides (straight, convex, concave) and base (entire, indented, concave) including height (Short = rondel is wider than it is tall, Tall = rondel is taller than it is wide). Although size can be used in the identification of phytoliths, it was thought prudent to stick to morphological features only.

Since starch identification was not the major focus of this thesis, only a few species were chosen for comparison (see Appendix A). Economically valuable plants used by native communities during the historic period chosen for this analysis, among others, include: yellow pond lilies (*Nuphar variegatum*), common beans (*Phaseolus vulgaris*), prairie breadroot (*Psoralea esculenta*), broad-leaved arrowheads (*Sagittaria latifolia*), cattails (*Typha latifolia*), maize (*Zea mays*), and wild rice (*Zizania aquatica* and *Zizania palustris*) (Moerman, 1998; Newmaster et al., 1997; Peterson, 1977).

Collected samples of comparative starch granules allowed for a tentative identification only of starch grains for species not found in the literature. Starch samples were also collected from key economic species in order to determine if they produce similar types to the ones described as being diagnostic of maize (*Zea mays*) and common beans (*Phaseolus vulgaris*).

However, additional comparative starch samples of economically important starchy plants should be analysed to give more secure identifications.

Comparative starch grains were extracted using different methods depending on the part of the plant sampled. Seeds were crushed using a clean pestle and mortar, and fruits or fibrous materials such as tubers or rhizomes were chopped and then crushed like the seeds to remove the starch from these materials. Water was usually added to these materials during the crushing to help with the extraction of the starch, and to minimize dust from the starch contaminating the lab. The material in the mortar was filtered in a 250 µm sieve to remove any unwanted organic materials which was poured in a 50 mL centrifuge tube. The remaining material was then centrifuged at 3000 rpm for 15 minutes, the supernatant was removed with new disposable pipettes and the remaining material was poured in a microcentrifuge tube in reagant alcohol, and then mounted onto slides. The starch grains were examined and photographed using a compound microscope equipped with XPL and DIC.

In order to make sense of the data that was collected, a cluster analysis program called Hierarchical Clustering Explorer was used (Seo, 2008). The purpose of using a cluster analysis program has one key goal: the grouping or segmenting of the samples into subsets or clusters in order to show the relation between the samples that are closely related to one another and the ones that are not (Manning et al., 2008). Hierarchical agglomerative clustering is presented in a diagram known as a dendrogram; this illustrates the fusions or divisions made at each successive stage of analysis (Lorr, 1983; Manning et al., 2008). Four types of hierarchical agglomerative clustering algorithms can be applied in order to define distance or similarity between clusters, they are known as single linkage clustering, complete linkage clustering, average linkage clustering, and average group linkage clustering (Manning et al., 2008). Single linkage clustering merges a pair of samples based on their two most similar elements, while complete linkage clustering merges a pair of samples based on their most dissimilar elements, and average and average group linkages is based on all similarities between samples (Manning et al., 2008). Because there is a lot of redundancy in rondel phytolith types from one plant to another, with only certain types occurring in one or very few plants, the best linkage method that illustrates which plants are most similar based on rondel types should be used.

6.3 LAKE SEDIMENTS

Lake sediment sampling for this project was done in July of 2006. The criteria used to determine which lake to core dependent primarily on two variables; small size and catchment, and having the historical existence of wild rice within the lake. A universal corer was used for sediment sampling on the side of a canoe in Lulu Lake (Rice Bay), near the town of Kenora (Figure 20).

When the samples were collected, wild rice was growing across the bay; some plants were still at their floating stage, while others were actually growing out of the water, of which, a few were pollinating. Although the core was not dated, the sediment samples are assumed to have been deposited recently, either historically or shortly before. Because a modern distribution of wild rice was present in the lake, it was hypothesized that phytoliths representative of the plant would be found in the sediment.

There were a few rivers around the lake, although the bay was quite sheltered from these, therefore it seemed that contamination from other sources seemed unlikely. However, many cottages are located around the lake and contamination is possible, especially in causing high growths of algae in the lake, thus increasing the diatom content, which waters down the phytolith population in samples.

The core was a massive (structureless) sapropel (Figure 21) , its total length measured 72 cm, and was taken in approximately 1.5 m of water; the core was sub-sampled on the shore at 2 cm intervals, using a core extruding apparatus, that were placed in individual sample bags.

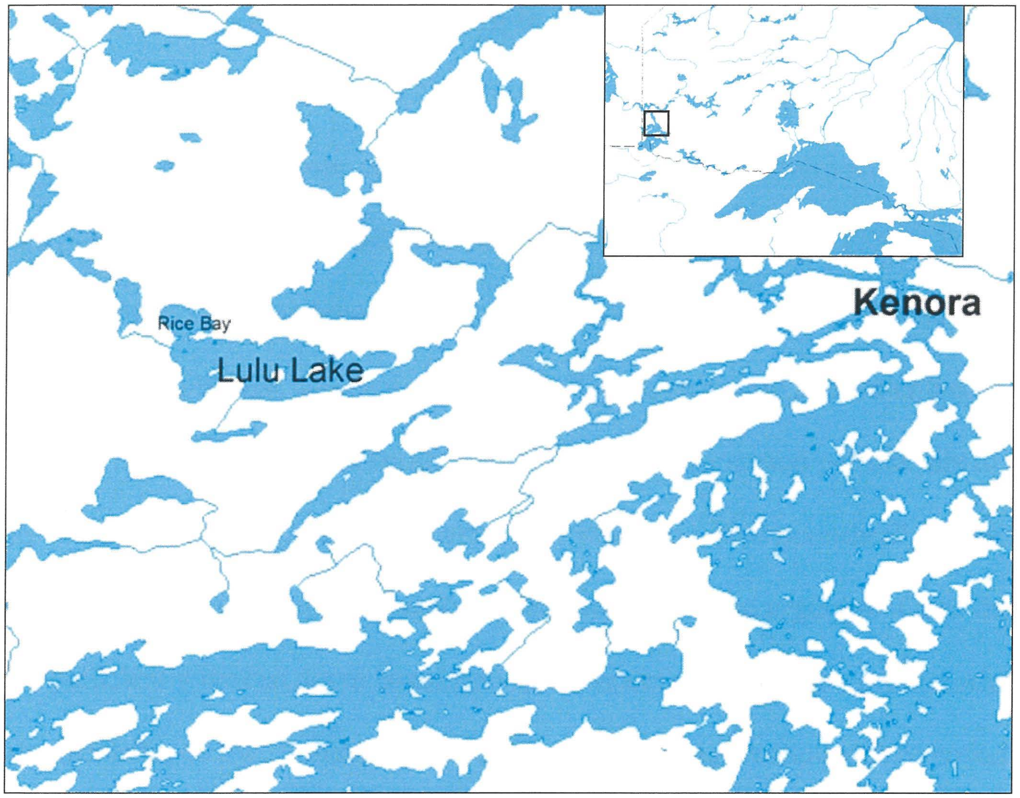

Figure 20. Location of Lulu Lake in relation to the town of Kenora.

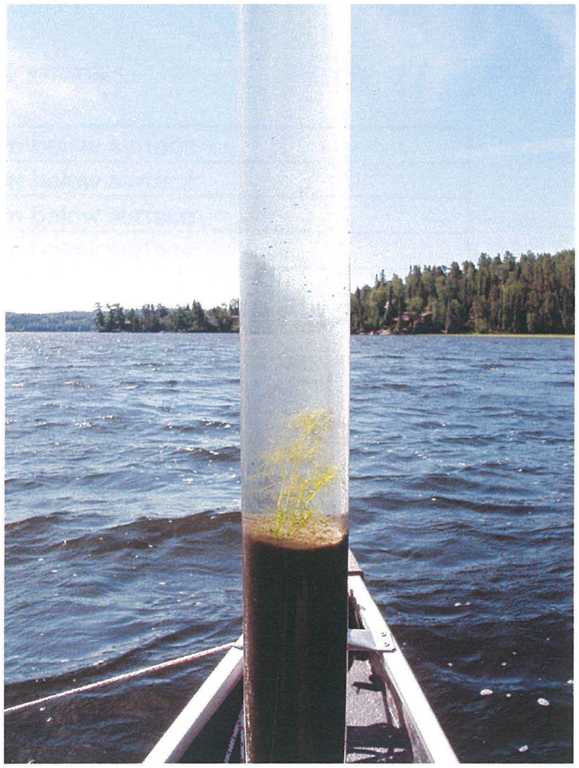

Figure 21. Massive sapropel extracted from Lulu Lake showing water-sediment interface.

The method used for extracting phytoliths from the lake sediments was modified from standards used by Staller and Thompson (2002) and Hart et al. (2003) for extracting microfossils from carbonized food residues. Four samples taken at 10 cm intervals were analysed to determine the presence of diagnostic wild rice rondel types in lake sediment (Table 3). Half a cubic centimetre was subsampled from each interval. Each sample was placed in 50% nitric acid (NHO_3) in a glass tube that was heated to near boiling temperature in a water bath for a period of 12 to 24 hours under a fume hood. Samples were gently stirred periodically to mechanically breakdown the organics. 50% nitric acid was also added periodically when needed to keep the reaction going in order to breakdown what was left of the organics. Once the samples were sufficiently broken down based on visual inspection, they were washed with distilled water, centrifuged for 15 minutes at 3000 rpm, and the supernatant was removed with new disposable pipettes; this last step was repeated five times.

Table 3. Lulu Lake sediment samples.

Sample 1	10-12 cm below surface
Sample 2	22-24 cm below surface
Sample 3	34-36 cm below surface
Sample 4	46-48 cm below surface

Removal of the clays from the sediment followed Boyd (2004). Settling was done in a 2.5 % calgon solution (5% sodium pyrophosphate). The sediments mixed with the calgon solution were put in a beaker up to an 8 cm line. Samples were stirred in the calgon solution with a bar magnet in order to mechanically break up the clays and left to settle for one hour. After settling for an hour the supernatant was removed with a clean pipette. The settling procedure was repeated until the supernatant was clear. Samples were screened with a clean 250 µm sieve to remove any loose inorganic materials that might have been remaining. The samples then were placed in reagent alcohol in a microcentrifuge tube and then mounted onto slides in

Entellen. The samples were examined and photographed using a compound microscope equipped with XPL and DIC. A minimum of 170 identified phytoliths were counted for each sample. Most phytoliths were classified according to Brown's (1984) key. Rondels were classified according to the taxonomy devised as part of this project.

6.4 CARBONIZED FOOD RESIDUES

For the purposes of this project, multiple pottery sherds were collected based on the presence of adhering carbonized food residues (Figure 22) during the summer of 2005 and 2006 from the Ministry of Citizenship, Culture and Recreation in Thunder Bay, Ontario. A few samples were also obtained from other sources such as collections from the Manitoba museum (one Sandy Lake sample from the Porth site (EaLa-2)), current sites examined by Jill Taylor-Hollings and Scott Hamilton, and from local collectors. With the help of Jill Taylor-Hollings, the pottery sherds were organized in a database according to site, part (rim, neck, body, base), and type based on stylistic attributes. In total, 1010 pottery sherds, yielding 645 samples from 42 archaeological sites were collected. However, only a subset of 36 samples were analyzed. Most identifiable pottery sherds consisted of rim and neck sherds but a few body sherds had identifiable traits. The main cultures represented by the ceramics consisted of Laurel (Middle Woodland period), Blackduck, Selkirk, and Sandy Lake (Late Woodland period) (see Appendix C).

Figure 22. Example of residue on a potsherd from the Lowton site (DiLv-3) showing octagonal shaped cracks, magnification 10X (Surette, 2005).

All pottery sherds were washed following excavation or during cataloguing, therefore, it was deemed unnecessary to wash the samples again and risk loosing some, or all of the fragile adhering carbonized food residues. Regardless, samples were examined under a dissecting microscope to make sure they were clean and had no soil particles adhering to the fabric. The residue on some samples came off with minor handling of the potsherds. A dental pick under 10X magnification was used to remove the residues on the potsherds. Since some samples consisted of reconstructed vessels, careful attention was taken not to scrape off the glue holding the pieces of pottery together. Following extraction from the pottery sherds, the carbonized food residues were further examined and cleaned of all contaminants (small roots, pieces of pottery fabric, etc). From the total assemblage collected, some samples yielded very little residue (1 mg) while others were very abundant (> 30 mg), thus allowing for multiple analyses.

Only a subset of 36 samples (Table 4), were analyzed for this project based on several criteria: the pottery sherds had clear stylistic attributes identifiable to the cultures mentioned above; had a suitable amount of carbonized food residue necessary for analysis; and, were from significant archaeological sites. Samples from 6 Laurel, 11 Blackduck, 1 Blackduck/Mixted traits, 8 Sandy Lake, 9 Selkirk, and 1 undetermined Late Woodland potsherd (the only exception to one of the criteria mentioned above) were chosen for analysis (Table 4). These samples came from 21 sites (Figure 6), some that included only one archaeological component and some that included many (Table 4). The pottery sherds used in this analysis range from the Winnipeg River area (including one from the Porth site in Manitoba), Lake of the Woods area, Lac Seul, and Rainy River area (Figure 6).

Table 4. Carbonized food residue samples analyzed.

Borden #	**Site Name**	**Sample #**	**Pottery Type**	**Sample Weight**
DcKc-1A	Lady Rapids	W2N17:IV	Sandy Lake	28.8 mg
DdKm-1	Long Sault	XU4:II	Blackduck	9.1 mg
DgKl-3	Nestor Falls	10:V, S V22 R38	Blackduck	9.7 mg
DiKp-3	Big George	Bag 66	Laurel	20.5 mg
DiKp-5	Arklow	A11, 8T	Selkirk	27.9 mg
DjKn-5	Bundoran	XU 21, 22, 23	Selkirk	17.6 mg
DjKn-5	Bundoran	XU16: I	Late Woodland	29.3 mg
DjKn-5	Bundoran	XU21:VII	Laurel	20.4 mg
DjKn-5	Bundoran	XU32:CII	Blackduck	25.2 mg
DjKp-3	Meek Site	22:B:VI	Sandy Lake	29.1 mg
DjKp-3	Meek Site	P2:T M158	Selkirk	22.9 mg
DjKp-3	Meek Site	XU15:V	Laurel	18.3 mg
DjKp-3	Meek Site	XU2:III	Blackduck	28.4 mg
DjKq-1	Spruce Point	XU1,2&4	Sandy Lake	29.8 mg
DjKq-1	Spruce Point	XU14:III	Blackduck	11.1 mg
DjKq-1	Spruce Point	XU21:V-12&XU21:VI-1	Selkirk	26.6 mg
DjKq-4	Ash Rapids East	XU10:VIII	Blackduck	23.5 mg
DjKq-4	Ash Rapids East	XU17:IV	Selkirk	28.4 mg
DjKq-4A	Ash Rapids East	Bag 343	Sandy Lake	17.1 mg
DkKn-1	Rushing River Park	Vessel # 7	Sandy Lake	29.2 mg
DkKp-8	Ballinacree	161:V V292 R930	Blackduck	26.8 mg
DkKp-8	Ballinacree	Pot # 235	Selkirk	29.7 mg
DkKp-9	Ballinamore	Pot # 15	Laurel	36.9 mg

Table 4. (Continued).

DkKp-9	Ballinamore	Pot # 5	Selkirk	23.9 mg
DkKr-2	Dowse	6:IV	Sandy Lake	26.3 mg
DkKr-4	Mud Portage Channel	T.P. 2 1978	Laurel	27.3 mg
DlKp-1	Fisk Site	TSI-A-VIII-F	Laurel	9.1 mg
DlKp-1	Fisk Site	XU4:V-7, R89	Blackduck	15.7 mg
EaLa-2	Porth	W333	Sandy Lake	25.3 mg
EcKc-4	Two Point Sand Bar	N/A	Sandy Lake	33.1 mg
EcKf-8	N/A	N6	Selkirk	24.7 mg
EdKb-1	Wapesi River	N/A	Blackduck	19.7 mg
EdKh-1	Wenasaga Rapids	4A	Blackduck	20.5 mg
EdKh-1	Wenasaga Rapids	Bag 119	Blackduck or Mixed Traits	32.2 mg
EdKh-1	Wenasaga Rapids	Bag 194	Selkirk	23.1 mg
EdKo-6	Rowdy Lake	317, T.P.5	Blackduck	13.0 mg

Between 9.1 mg and 36.9 mg of carbonized residue were processed for phytoliths/starch analysis (Table 4). The method used for extracting phytoliths from the carbonized food residues followed standards devised by Staller and Thompson (2002) and Hart et al. (2003). Each sample was placed in 50% nitric acid (NHO_3) in a glass tube that was heated to near boiling temperature in a water bath for a period of 12 to 24 hours under a fume hood. Samples were gently stirred periodically to mechanically breakdown the residue. Nitric acid was also added periodically when needed to keep the reaction going in order to breakdown what was left of the residue. Once the samples were sufficiently broken down, they were washed with distilled water, centrifuged for 15 minutes at 3000 rpm, and the supernatant was removed with new disposable pipettes; this last step was repeated five times. The samples were placed in reagent alcohol in a microcentrifuge tube and then mounted onto slides in Entellen. The carbonized food residues were examined and photographed using a compound microscope equipped with XPL and DIC.

A minimum of 250 identified phytoliths were counted for each sample (with the exception of four samples where maize and/or wild rice were identified but the samples are incomplete), not including starch grains, diatoms, and pollen grains which were also counted; however, no minimum count was considered for any of these proxies. Most phytoliths were classified according to Brown's (1984) and Twiss et al.'s (1969) taxonomic keys; however, rondels were classified according to the taxonomy devised as part of this project (see Appendix B).

Starch grains were analysed and photographed under plane and crossed polarized light and classified based on the criteria developed for maize (*Zea mays*) identification (starches with an X or Y fissure, a 90° extinction cross, and > 20 μm in diameter) by Pearsall et al. (2004b). Tentative identification of common bean (*Phaseolus vulgaris*) followed descriptions found in Su et al. (1998) and Hoover and Ratnayake (2002). Starch granules with an X or Y fissure, a 90° extinction cross, and > 20 μm in diameter were counted as maize (Pearsall et al., 2004b), while starch granules with the same features except being < 20 μm in diameter were counted as "possible maize". Identification of other starch grains was done based on comparison with local economic plants; however, only a small sample of plants were collected and therefore only allows for a tentative identification.

CHAPTER 7. RESULTS

7.1. INTRODUCTION

In this chapter, the data collected from the analyses conducted during this project is reviewed. First the results from the analysis of comparative materials, especially the phytoliths, are discussed. Since starch granules were not a main focus of this thesis, only some of the preliminary observations made, are described. The second section of this chapter will look at the results from the lake sediments. The final section will look at the results from the analysis of the carbonized food residues.

7.2. COMPARATIVE PLANT SPECIMENS

7.2.1. Phytoliths from Comparative Grasses

Over 11, 000 identifiable rondel phytoliths were photographed, counted and sorted based on morphology from 38 plants including two varieties of *Oryzopsis* sp. (*Oryzopsis asperfolia* and *Oryzopsis pungens*) and two varieties of *Zizania* sp. (*Zizania aquatica* and *Zizania palustris*), of which three samples were *Zizania palustris* for a total or 40 samples (Table 5). Other grasses such as *Oryzopsis canadensis* and *Hierochloe odorata* were also analyzed but are not included in the results since the counts were too low, or because the plant parts analyzed did not produce any rondels. Samples from plants other than grasses produced no rondel "confusers"; however sedges did produce trichome types seen in grasses. These particular grass species were chosen because they are native to the area with the exception of maize (*Zea mays*), and still grow in the area today.

Table 5. Grasses analyzed for phytolith content as discussed in chapter 6.

Scientific Name	Common Name	Portion Analyzed
Agrostis scabra	Rough bentgrass	Inflorescence, Leaf
Alopecurus aequalis	Shortawn foxtail	Inflorescence, Leaf
Andropogon gerardii	Big bluestem	Inflorescence, Leaf
Beckmannia syzigachne	Slough grass	Inflorescence, Leaf
Bromus ciliatus.	Fringed brome	Inflorescence, Leaf
Calamagrostis canadensis	Canada bluejoint	Inflorescence, Leaf
Cinna latifolia	Drooping woodreed	Inflorescence, Leaf
Danthonia spicata	Poverty grass	Inflorescence, Leaf
Deschampsia cespitosa	Tufted hairgrass	Inflorescence, Leaf
Dichanthelium acuminatum	Hairy panicgrass	Inflorescence, Leaf
Distichlis spicata	Salt grass, spike grass	Inflorescence, Leaf
Elymus Canadensis	Canada wildrye	Inflorescence, Leaf
Eragrostis hypnoides	Teel lovegrass	Inflorescence, Leaf
Festuca rubra	Red fescue	Inflorescence, Leaf
Glyceria grandis	Tall manna grass	Inflorescence, Leaf
Graphephorum melicoides	Melic oats	Inflorescence, Leaf
Hesperostipa comata	Speargrass	Inflorescence, Leaf
Hordeum jubatum	Foxtail barley	Inflorescence, Leaf
Koeleria macrantha	Junegrass	Inflorescence, Leaf
Leersia oryzoides	Rice cutgrass	Inflorescence, Leaf
Milium effusum	Millet grass	Inflorescence, Leaf
Muhlenbergia glomerata	Marsh muhly	Inflorescence, Leaf
Oryzopsis asperifolia	Rough-leaved ricegrass	Inflorescence, Leaf
Oryzopsis pungens	Northern rice grass	Inflorescence, Leaf
Panicum capillare	Witchgrass	Inflorescence, Leaf
Pascopyrum smithii	Western wheatgrass	Inflorescence, Leaf
Phalaris arundinacea	Reed canary grass	Inflorescence, Leaf
Phragmites australis	Common reed	Inflorescence, Leaf
Poa palustris	Fowl meadow grass	Inflorescence, Leaf
Schedonorus pratensis	Meadow fescue	Inflorescence, Leaf
Schizachne purpurascens	False melic	Inflorescence, Leaf
Sphenopholis intermedia	Prairie wedgegrass	Inflorescence, Leaf
Sporobolus neglectus	Puffsheath dropseed	Inflorescence, Leaf
Torreyochloa pallida	Fernald's false mannagrass	Inflorescence, Leaf
Trisetum spicatum	Spike trisetum	Inflorescence, Leaf
Zea mays	Maize	Cob, Leaf
Zizania aquatica	Wild rice	Inflorescence, Leaf
Zizania palustris	Northern wild rice	Inflorescence, Leaf, Stem

Phytolith types from cultivars such as common beans (*Phaseolus vulgaris*) and squash (*Cucurbita* sp.), were also photographed to be used for comparison. Phytoliths from plants other than grasses were not counted since the main focus was on rondels; therefore they were only used for comparison. However, because of their possible confusion with rondels, identifiable trichomes and crosses from grasses were also counted and classified. Trichomes were identified based on their triangular or cone-shaped appearance, while crosses were identified based on the four indentations in the base in the shape of a cross. Rondels occurred commonly in the infloresence of grasses but were not always present in the leaves or stems.

As stated in chapter 6, a minimum of 300 rondel phytoliths, in total, were counted for each grass sample. However, one sample with a rondel count of 131 (see Appendix E) was also included in this study. Rondel types were sorted based on a combination of morphological features (Figure 23): the shape of the top (flat, spiked, wavy), sides (straight, convex, concave) and base (entire, indented, concave, concave and indented) including height (Short = rondel is wider than it is tall, Tall = rondel is taller than it is wide) (see appendix B for definitions).

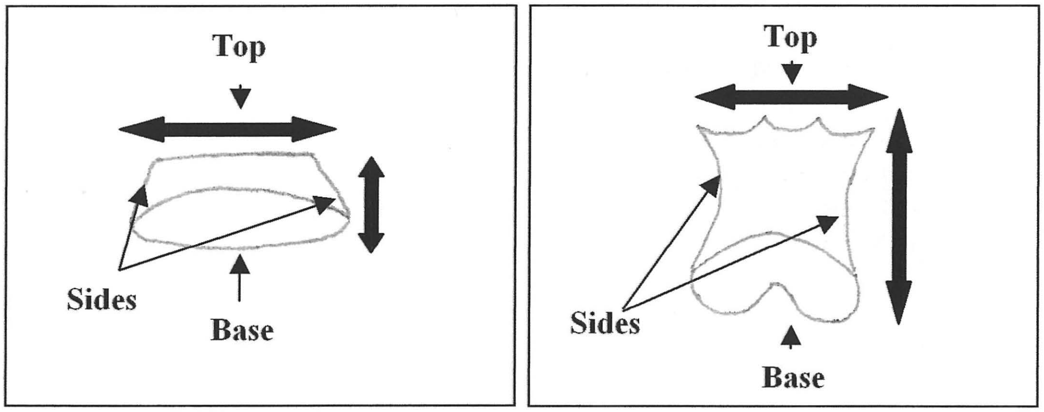

Figure 23. Rondel Morphology: short (width < height) (left) and tall (height > width) (right).

A phytolith key was devised to sort the morphotypes observed (see Appendix B). It also defines important morphological terminology used in this discussion. In total, 334 morphotypes were distinguished. These morphotypes are divided into three basic categories based on the shapes of their tops; one that takes into consideration the presence or absence of projections, the second considers the overall shape of the top, while the third focuses on the actual shapes or number of projections (Table 6). After characteristics of the top are identified, the rondels are further divided based on the shape of their bases, sides, and height (see Appendix B).

Table 6. Basic divisions of rondel tops.

Presence/Absence of Projections	Shape of Top	Shape/Number of Projections on Top
No Projections	Flat Top (1A)	
	Rounded Top (1B)	
	Three Sided Top (1C)	
Projections	Non-Spiked (2)	Flat (2A)
		Rounded (2B)
		Wavy (2C)
		Flat and Wavy (2D)
	Spiked (3)	One Spike (3A)
		Two Spikes (3B)
		Three Spikes (3C)
		Four Spikes (3D)
		Five Spikes (3E)
		Six Spikes (3F)
		Seven Spikes (3G)
		Eight Spikes (3H)
		Nine Spikes (3I)
	Spikes and Waves (4)	Two Projections (4A)
		Three Projections (4B)
		Four Projections (4C)
		Five Projections (4D)
		Six Projections (4E)
		Seven Projections (4F)
		Eight Projections (4G)
		Nine Projections (4H)
		Ten Projections (4I)
	Flat and Spiked (5)	Two Projections (5A)
		Three Projections (5B)
		Four Projections (5C)
		Five Projections (5(D)
		Six Projections (5E)
	Flat, Spiked and Wavy (6)	Three Projections (6A)
		Four Projections (6B)
		Five Projections (6C)

Wild rice (*Zizania aquatica* and *Zizania palustris*) tends to be dominated mostly by tops with spiked projections (Figure 24) compared to maize (*Zea mays*), where over 50% of the assemblage is dominated by types with no projections and projections that aren't spiked (Figure

24). Wild rice also tends to be dominated by indented rondels compared to maize (Figure 25), which is dominated by entire bases. Interestingly, in both maize and wild rice concave bases and concave and indented bases do not appear very often. Only seven species were high producers of concave base types, some of which are edible.

In order to check the redundancy and multiplicity of rondels in the comparative plants, the occurrence of rondel types in each plant sample was broken down into Very Rare (VR), Rare (R), (Common), and Very Common (VC) (Table 7) based on their percentages (see Appendix D). This was also done for the totals of each rondel types for all plants (Appendix D). Types that are commonly found in one plant but not the total plant assemblage are identified as diagnostic types. Types commonly found in multiple species are not identified as diagnostic. If a type is very rarely or rarely found in one species and not in others it is also not considered diagnostic. The implication here is that more than one individual plant from a given species needs to be examined in order to understand phytolith assemblage variability (Mulholland et al., 1990). Some rondel types commonly found in one plant also appeared very rarely in one or more plants. Because very rare to rare types would be more likely to occur randomly, and because they are not under genetic control, their appearance in plant samples could be hit-or-miss, or a function of sample size. Therefore, with larger sample sizes, it might be possible to determine if the types commonly found in the one plant and rarely in another, could potentially be used to identify the species, at least when looking at the assemblage as a whole.

Table 7. Occurrences of types in the total assemblage.

Percentage of Total Assemblage	**Number of Rondels Represented by Percentage in 300**
Very Rare (VR) = (= or <1%)	1 - 3 Rondels
Rare (R) = (>1% or equal to 2%)	4 - 6 Rondels
Common (C) = >2 % to 5%	7 - 15 Rondels
Very Common (VC) = >5%	>15 Rondels

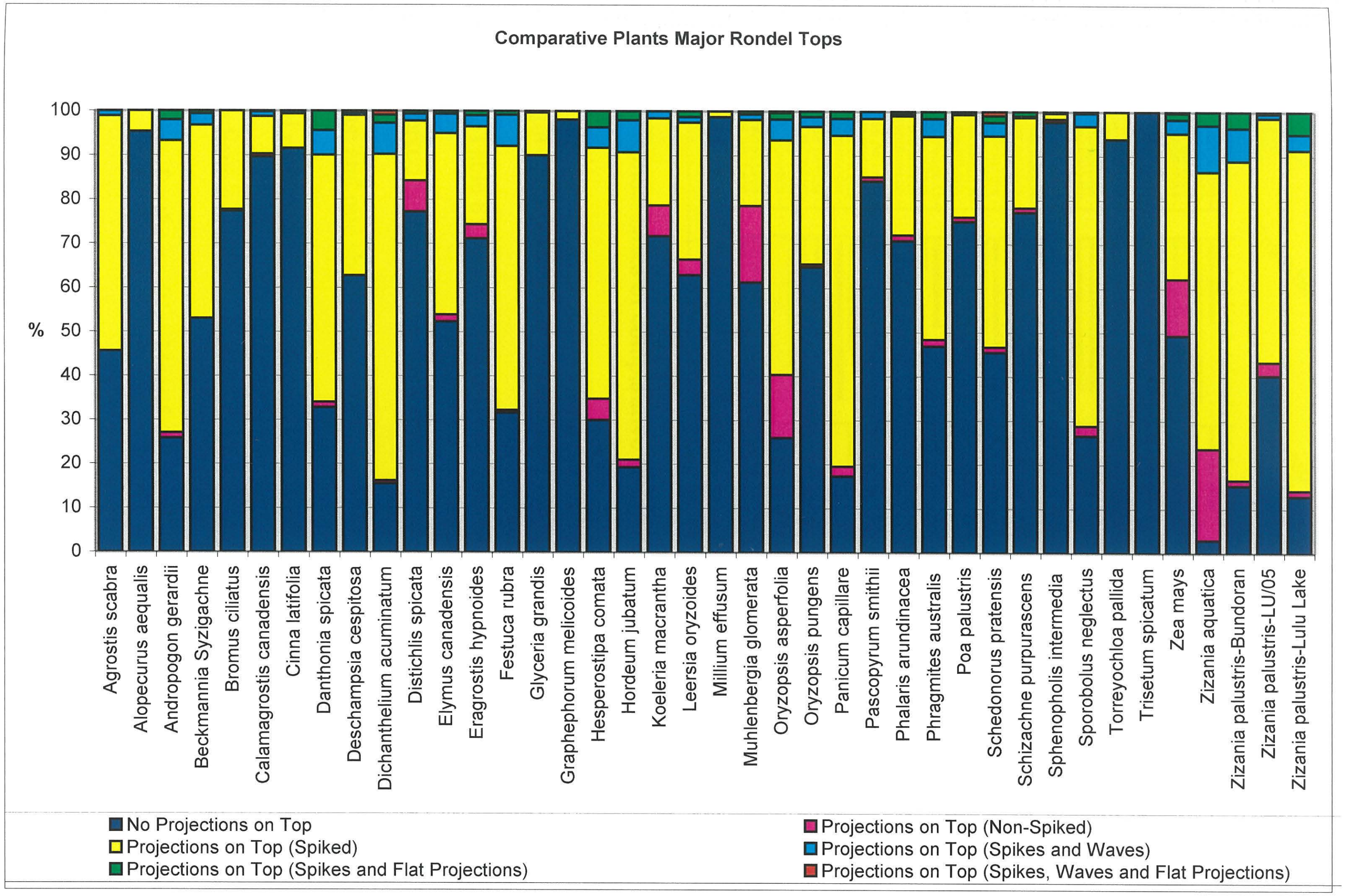

Figure 24. Major rondel tops of comparative plants samples.

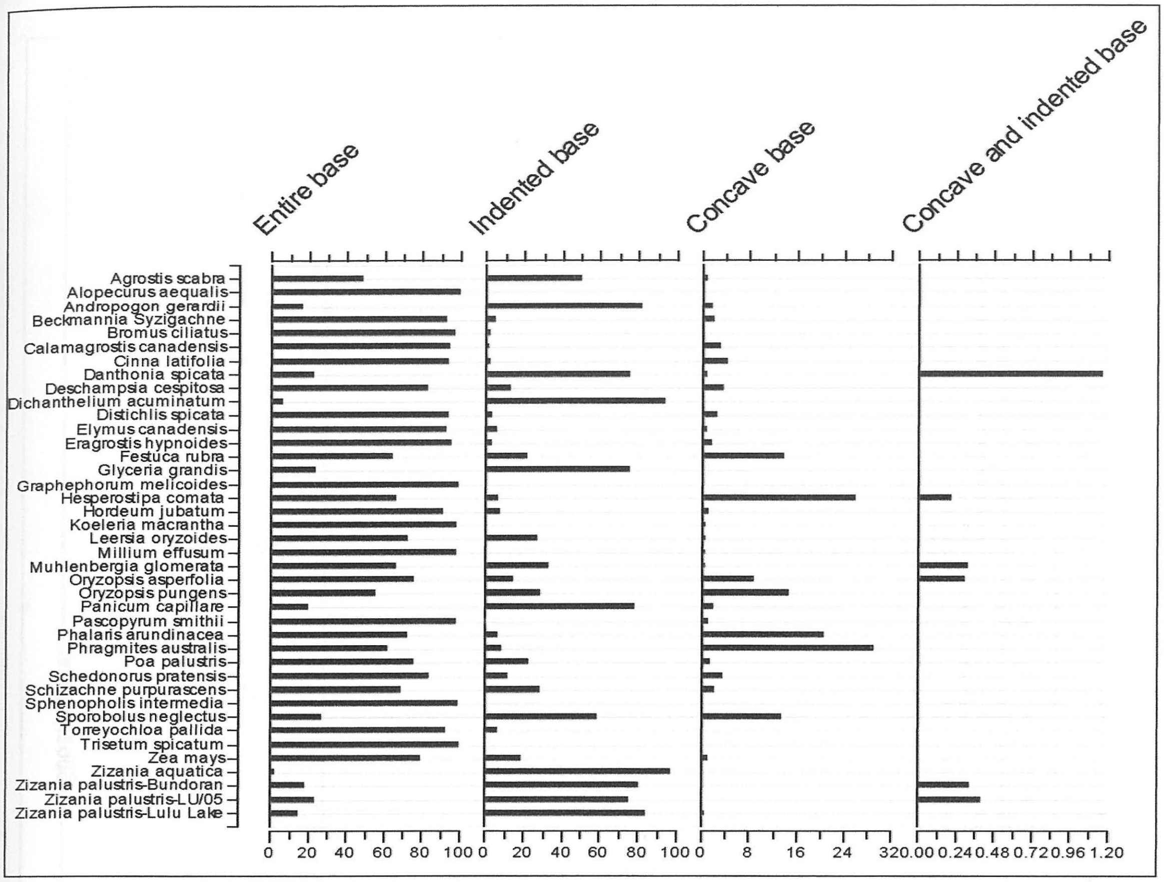

Figure 25. Rondel bases of comparative plants samples.

Eight rondel types occurred commonly in both species of wild rice (*Zizania* sp.) only (Figure 26, Table 8), which included: two tall three-spiked rondels with 2 and 3 indentations; five four-spiked rondels, three were tall with 1-3 indentations, and two were short with 1 and 3 indentations; and one short five-spiked rondel with 3 indentations (Figure 27; Table 8). The four-spiked rondels with one indentation and the ones with three indentations are the only types that do not have a similar feature (i.e., short, tall) found in another species, and are therefore most desirable for the positive identification of wild rice.

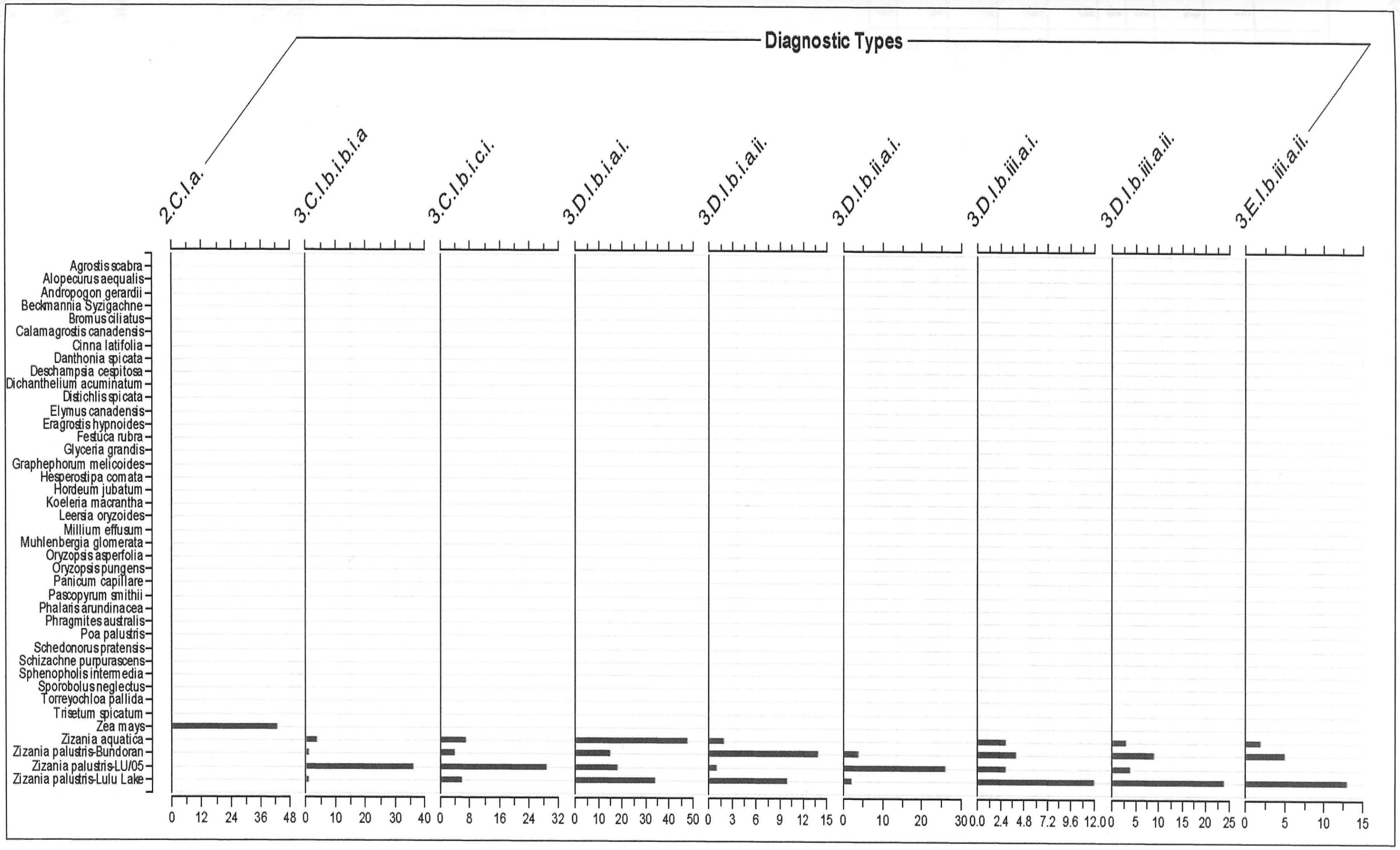

Figure 26. Rondel counts of types only occurring in maize (*Zea mays*) and wild rice (*Zizania* sp.).

Table 8. Key to Figures 26, 27 and 28. Description of diagnostic rondel types for wild rice (*Zizania* sp.) and maize (*Zea mays*).

	Rondel Classification Code	**Description**
1	**3.C.I.b.i.b.i.a**	Tall, three-spiked rondel with two indentations, one on either side of the base
2	**3.C.I.b.i.c.i.**	Tall, three-spiked rondel with three indentations, one in the centre and one on either side of the base
3	**3.D.I.b.i.a.i.**	Tall, four-spiked rondel with one indentation in the centre of the base
4	**3.D.I.b.i.a.ii.**	Short, four-spiked rondel with one indentation in the centre of the base
5	**3.D.I.b.ii.a.i.**	Tall, four-spiked rondel with two indentations, one on either side of the base
6	**3.D.I.b.iii.a.i.**	Tall, four-spiked rondel with three indentations, one in the centre and one on either side of the base
7	**3.D.I.b.iii.a.ii.**	Short, four-spiked rondel with three indentations, one in the centre and one on either side of the base
8	**3.E.I.b.iii.a.ii.**	Short, five-spiked rondel with three indentations, one in the centre and one on either side of the base
9	**2.C.I.a.**	Short, wavy-top rondel with entire base

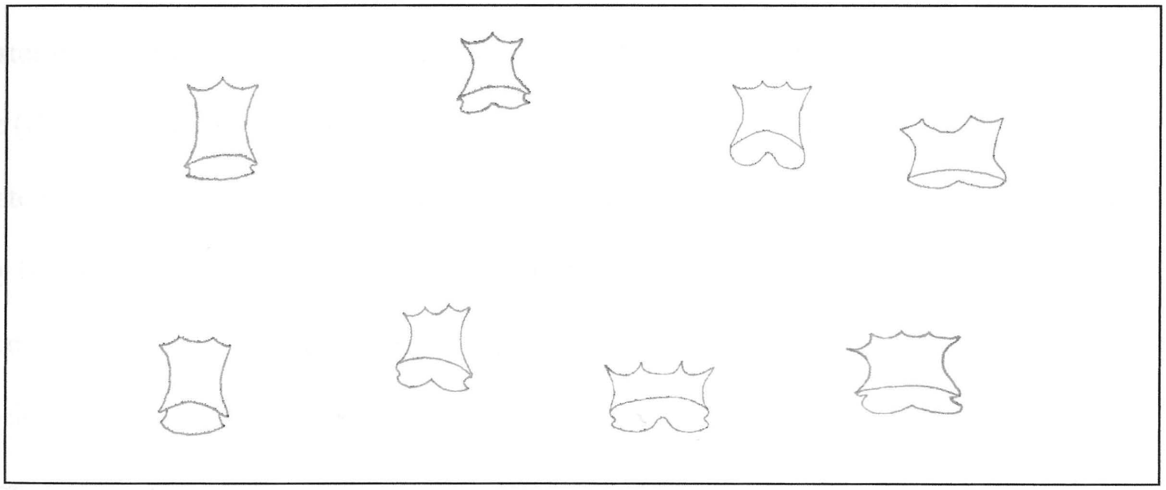

Figure 27. Rondel types diagnostic of wild rice: top row: 1-4 (Table 8), bottom row: 5-8 (Table 8).

Even though wavy-top rondels occurred in many species, maize (*Zea mays*) was the only species to have both a wavy-top and an entire base (Figure 28). Also, it was noted that the crest and trough of the wave of maize rondels, although opposite, are of almost similar width and height and are near mirror opposites.

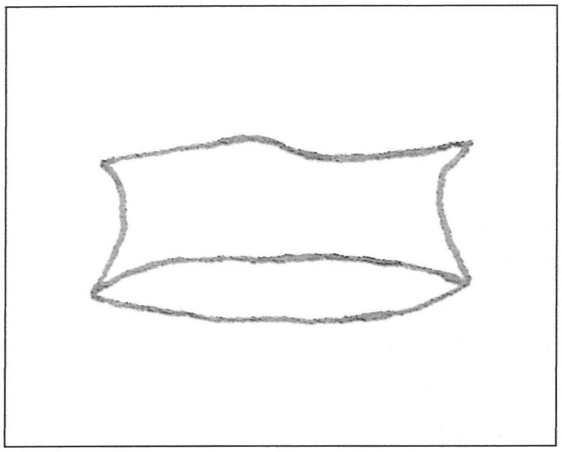

Figure 28. Typical wavy-top rondel from maize (Zea mays) (see number 9, Table 8).

Hierarchical clustering of the data shows that all four samples of wild rice group together, and are separate from other plants (Figure 29). Wild rice is also located on a similar branch of the dendrogram as other plants that had high quantities of indented rondels. Based on the clustering illustrated in the dendrogram, the phytolith assemblage of maize (*Zea mays*) and wild rice (*Zizania* sp.) are clearly very different (Figure 29). However, it is interesting that maize clusters with plants that were high in concave bases (Figure 25), although the similarities here may be based on other types of rondels. Interestingly, wild rice clusters away from plants such as common reed (*Phragmites australis*) that tend to thrive in similar environments. The two species of Indian rice grass (Oryzopsis sp.) also plotted together. Since rice cutgrass (*Leersia oryzoides*) is related to wild rice (Ge et al., 2002), it is not suprising that it clusters on a branch near it.

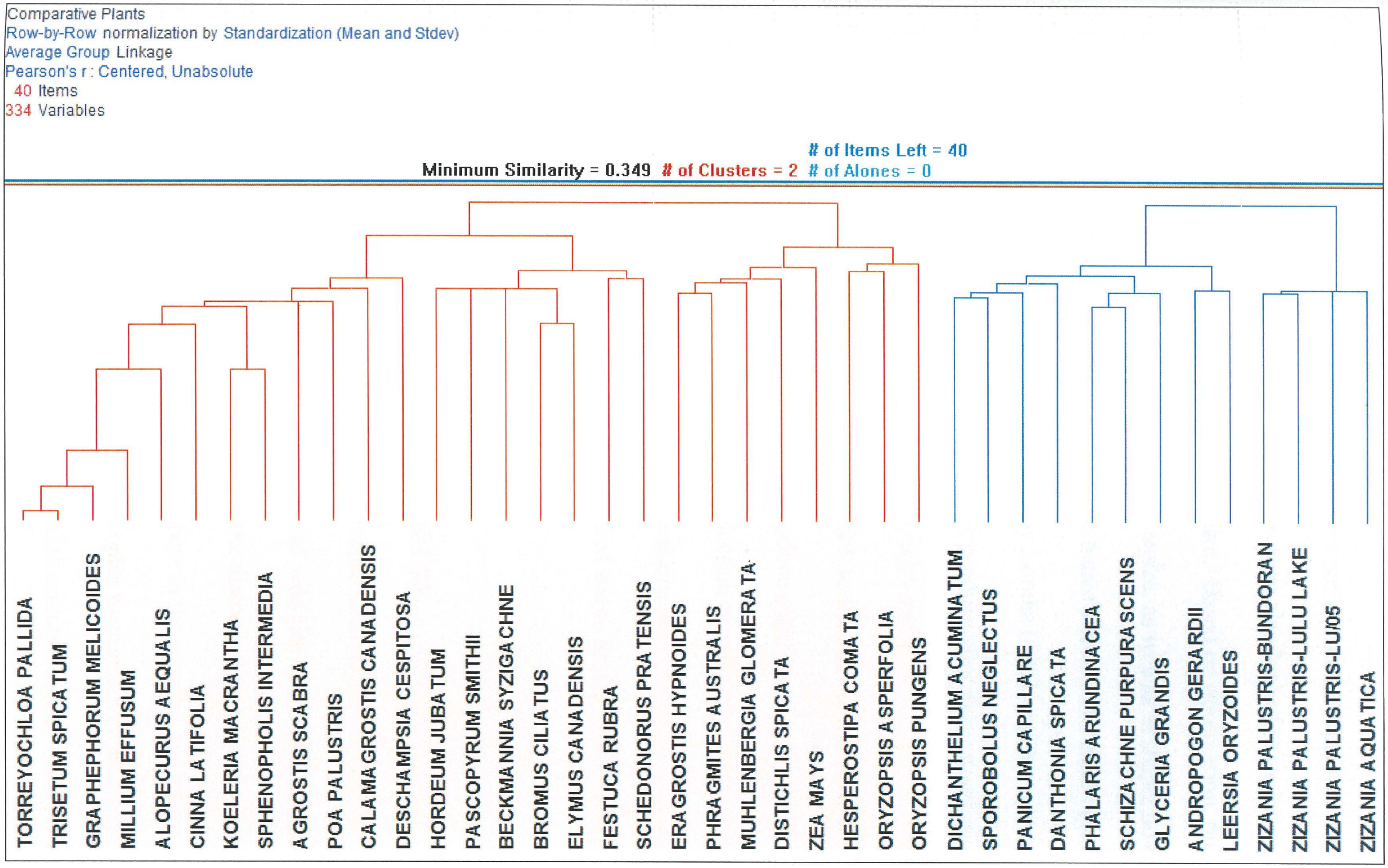

Figure 29. Hierarchal clustering of comparative plants based on rondel types. The average group linkage algorithm used here shows the most desirable grouping of the samples.

7.2.2. Observations of the Comparative Starch Samples

Extracted starch granules from a few comparative plants samples were examined for comparison purposes only. The starch grains were not counted or further analyzed since this was not the major focus of this thesis. However, they were also looked at to determine whether or not they could be confused with the starch of maize. Based on observation, only a few plants examined produced starch grains close in size to maize, as well as in shape; however none of the starch granules looked at appeared to fully mimic maize starch. The starch grains of immature wild rice seeds tended to be small, as described by Lorenz (1981), with a few occasional large grains. Although, parched wild rice seeds did not produce very many starch grains, they did produce grains similar in size and shape to maize, with similar fissuring; however, there was a major difference, the fissures did not appear as thick as the ones found in maize (see Sagittaria latifolia below in Figure 39). Other plants did produce other starch grains with similar fissures as maize; however the grains varied in shape, extinction cross, as well as grain thickness. In order to verify if some of these preliminary observations are correct, more work is needed, which would be a great help in interpreting the unidentified starch grains recovered from carbonized food residues.

7.3. LAKE SEDIMENTS: PHYTOLITH RESULTS

Only four samples were analysed from the core taken from Rice Bay in Lulu Lake, since the focus was kept on determining if the presence of wild rice could be detected using the types described above. All phytolith types were recorded, diatoms were on the other hand omitted from the counts since they appeared in great numbers in the samples and where not the focus of this analysis, no starch granules were present. Samples were taken at intervals of 10 cm, and each sample consisted of 2 cm of sediment. Phytolith counts ranged from 176 to 340 per sample. Samples consisted mainly of elongate plates, rondels, saddles, and trapezoids (Figure 30).

Rondels diagnostic of wild rice were found in only two of the samples (Figure 30). Another rondel that occured only rarely in wild rice was found in another sample and was categorized as possible evidence of wild rice (i.e., cf. *Zizania*) (Figure 30); however more work needs to be done to determine if the rondel type can be used to identify wild rice. Therefore, in only two of the samples, wild rice is considered positively identified; from the 10 to 12 cm bs (below surface) and the 22 to 24 cm bs (below surface) samples (Figure 31). It was also noted that rondels with concave bases were also present in the lake sediment.

7.4. CARBONIZED FOOD RESIDUES: PHYTOLITH AND STARCH RESULT

In this section, results of the analysis done on 36 samples of carbonized food residues from various ceramic types is discussed. Samples from 6 Laurel, 11 Blackduck, 1 Blackduck/Mixed Traits (Laurel-Blackduck transition), 9 Selkirk, 8 Sandy Lake, and 1 unidentified Late Woodland vessel are represented. The ceramics represented here are from 21 archaeological sites from the Lake of the Woods, Rainy River/Lake, Winnipeg River, and Lac Seul area.

The presence of wavy top rondels (Figure 32) as described by Pearsall et al. (2003), diagnostic of maize (*Zea mays*) were found in 24 of the 36 samples, from 17 of the 21 archaeological sites (Figure 33). Maize (*Zea mays*) was found in the carbonized food residues of 2 Laurel, 10 Blackduck, 1 Blackduck/Mixed Traits (Laurel-Blackduck transition), 4 Selkirk, 6 Sandy Lake, and 1 Late Woodland vessel (Table 9).

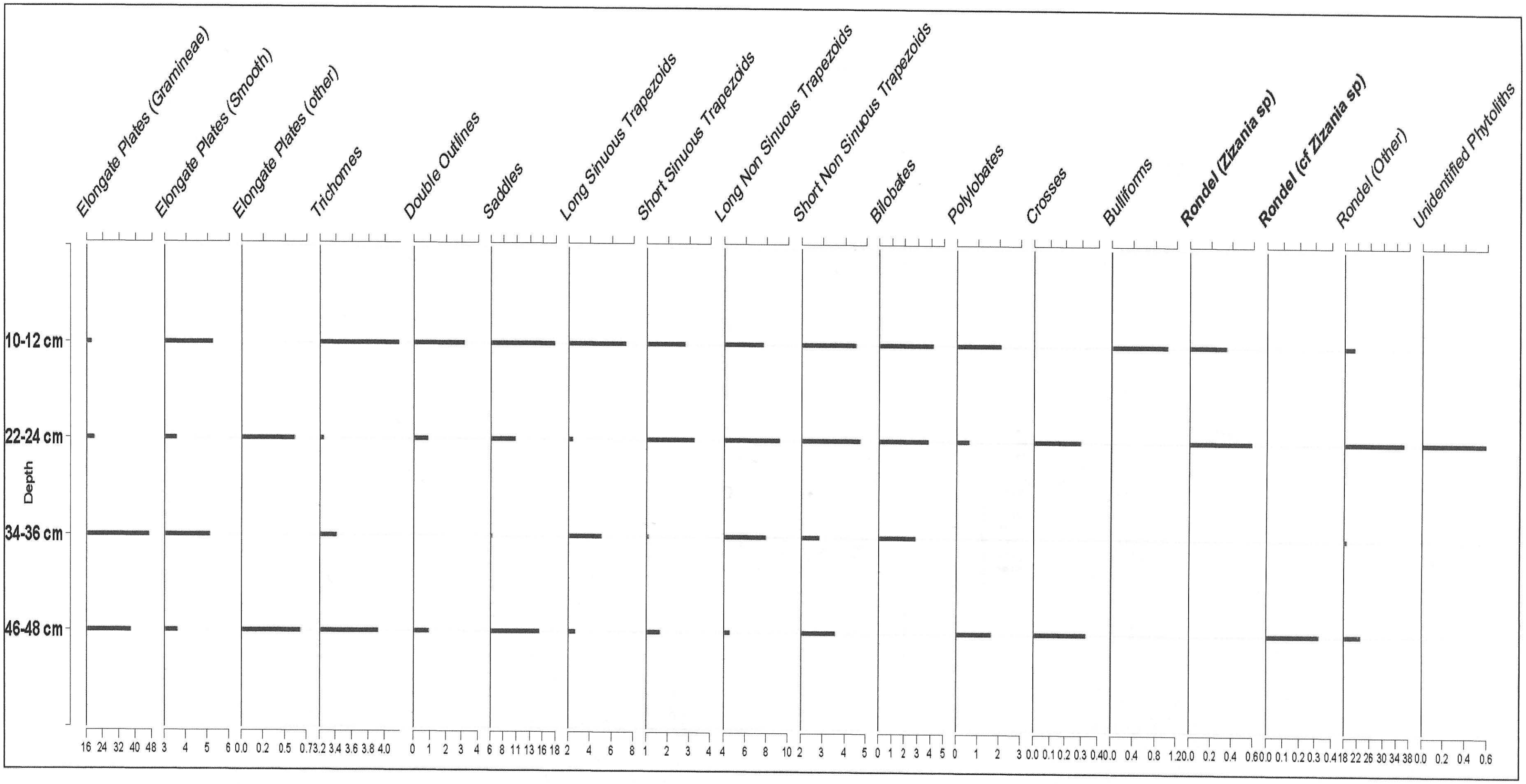

Figure 30. Phytoltihs found in lake sediment from Lulu Lake (the lithology is a uniform sapropel).

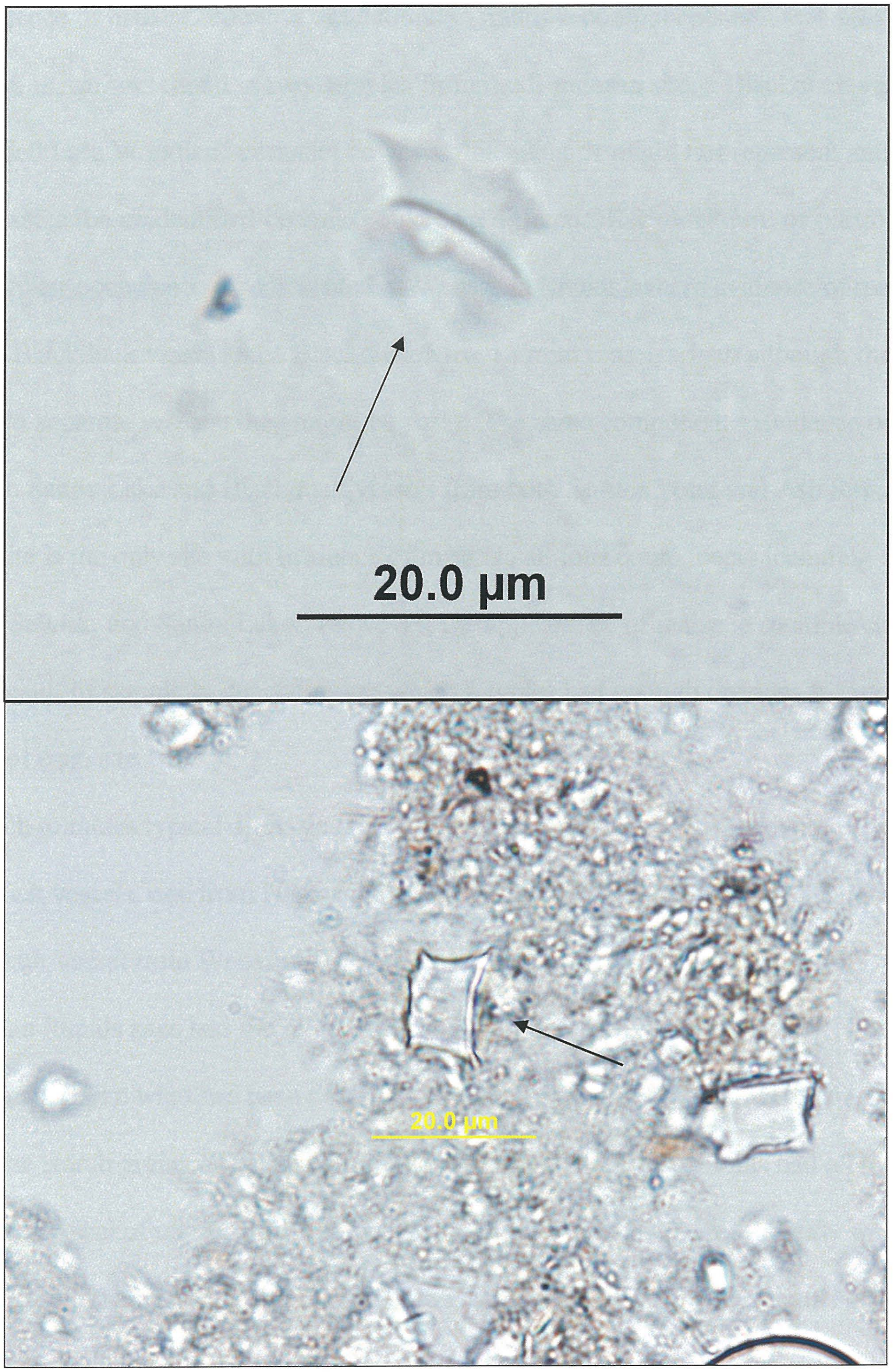

Figure 31. Microscopic images of comparative (top) and fossil wild rice phytoliths in sediment from Lulu Lake (depth = 22-24 cm) (bottom). Both are examples of short, four-spiked rondels with one indentation in the centre of the base.

Evidence of maize (*Zea mays*) was found in multiple components at a few sites (Table 9). For example, maize was found in two samples from the Bundoran site, a Blackduck vessel and an unidentified Late Woodland ceramic; however this might or might not represent another component since the unidentified ceramic could be a different Blackduck pot, or part of the same vessel. A similar occurrence is represented at Wenasaga Rapids, where evidence of maize is present in a Blackduck vessel and a Blackduck/Mixed Traits vessel, which although they are evidently two separate vessels, they might be part of the same component. Evidence of maize was found in Sandy Lake and Blackduck vessels from both Spruce Point and Ash Rapids East. The Meek site is the only site with evidence of maize in all four components including Laurel, Blackduck, Selkirk, and Sandy Lake. However, the appearance of maize in multiple components might be a result of sampling, depending on which samples had enough residues from each component of each site.

Starch granules typical of maize (Pearsall et al., 2004b) were also recovered at three sites: two Blackduck vessels, one from Nestor Falls (Figure 34) and another from the Bundoran site, and one Selkirk vessel from Wenasaga Rapids. Each of the starch granules from the Bundoran and Wenasaga Rapids sites had the morphology of starch granules typical of maize; however they were smaller than what has been described (Pearsall et al., 2004b) and were labelled as possible maize starch grains. The starch granule recovered from Nestor Falls had all the characteristics typical of maize, while the ones from the Bundoran site are a slightly smaller. Since maize phytoliths were recovered from both Blackduck samples from Nestor Falls and the Bundoran site, it is likely that the starch grains recovered came from maize, even though the ones from the Bundoran site are smaller. Since there were no maize phytoliths recovered from the Selkirk vessel from Wenasaga Rapids, the starch granule alone cannot support the evidence of maize in this sample.

Evidence of phytoliths diagnostic of wild rice (*Zizania* sp.) (Figure 35), as described in this study (Figure 27, Table 8), were found in 11 of the 36 samples, from 9 of the 21 archaeological sites (Figure 33, Table 9). Wild rice (*Zizania* sp.) was found in the carbonized food residue of 2 Laurel, 4 Blackduck, 3 Selkirk, and 2 Sandy Lake vessels. Ash Rapids East was the only site with evidence of wild rice in multiple components. Wild rice was found in the Blackduck, Selkirk, and Sandy Lake ceramics at this site.

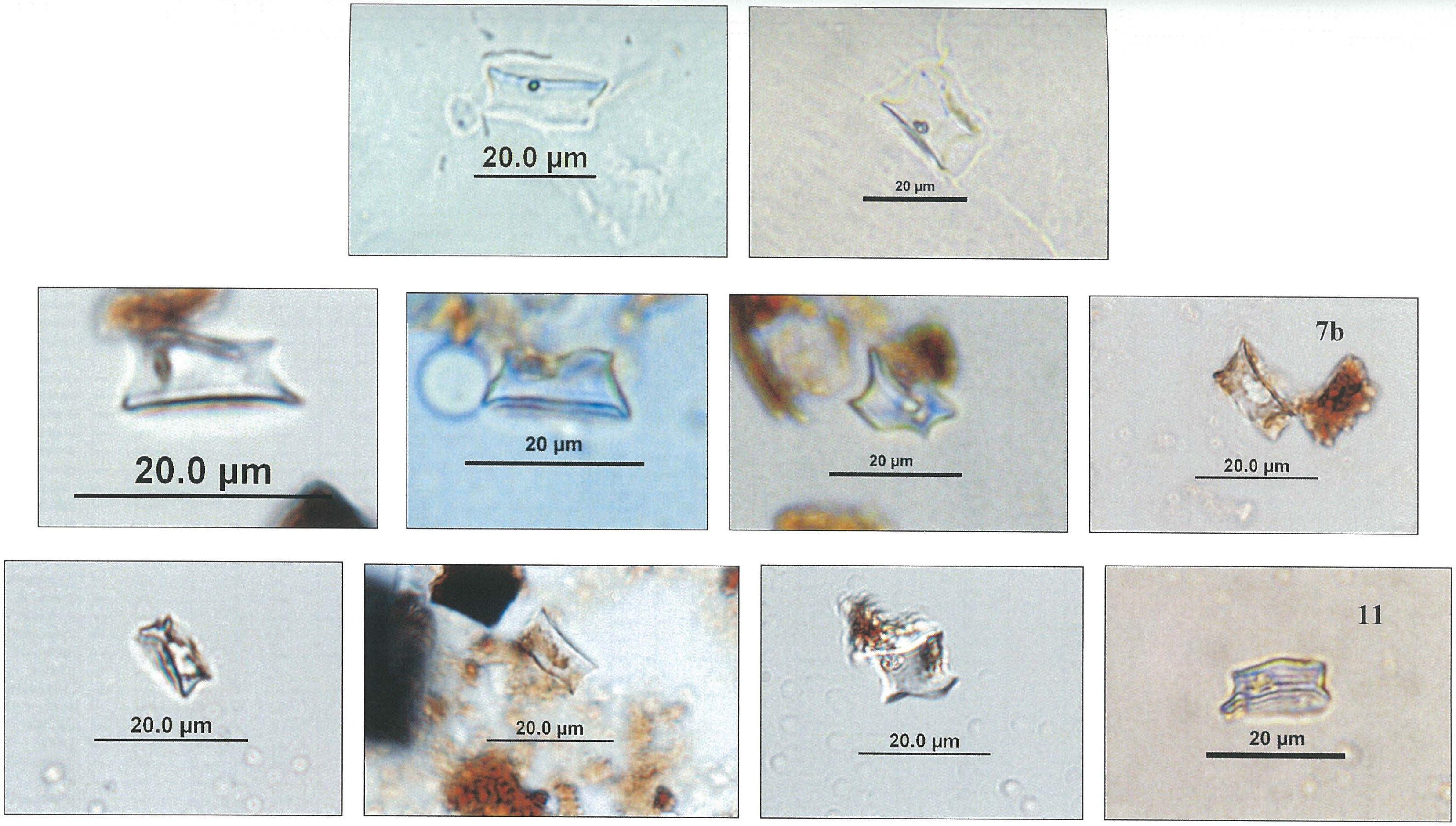

Figure 32. Microscopic images of maize (*Zea mays*) rondel phytoliths from comparative and archaeological samples. Top row = two maize phytolith from comparative "Mandan corn"; middle row = maize phytoliths from Arklow (Selkirk), Big George (Laurel) Bundoran (Late Woodland), and Dowse (Sandy Lake); bottom row = maize phytoliths from Lady Rapids (Sandy Lake), Meek (Laurel and Selkirk), and Rowdy Lake (Blackduck).

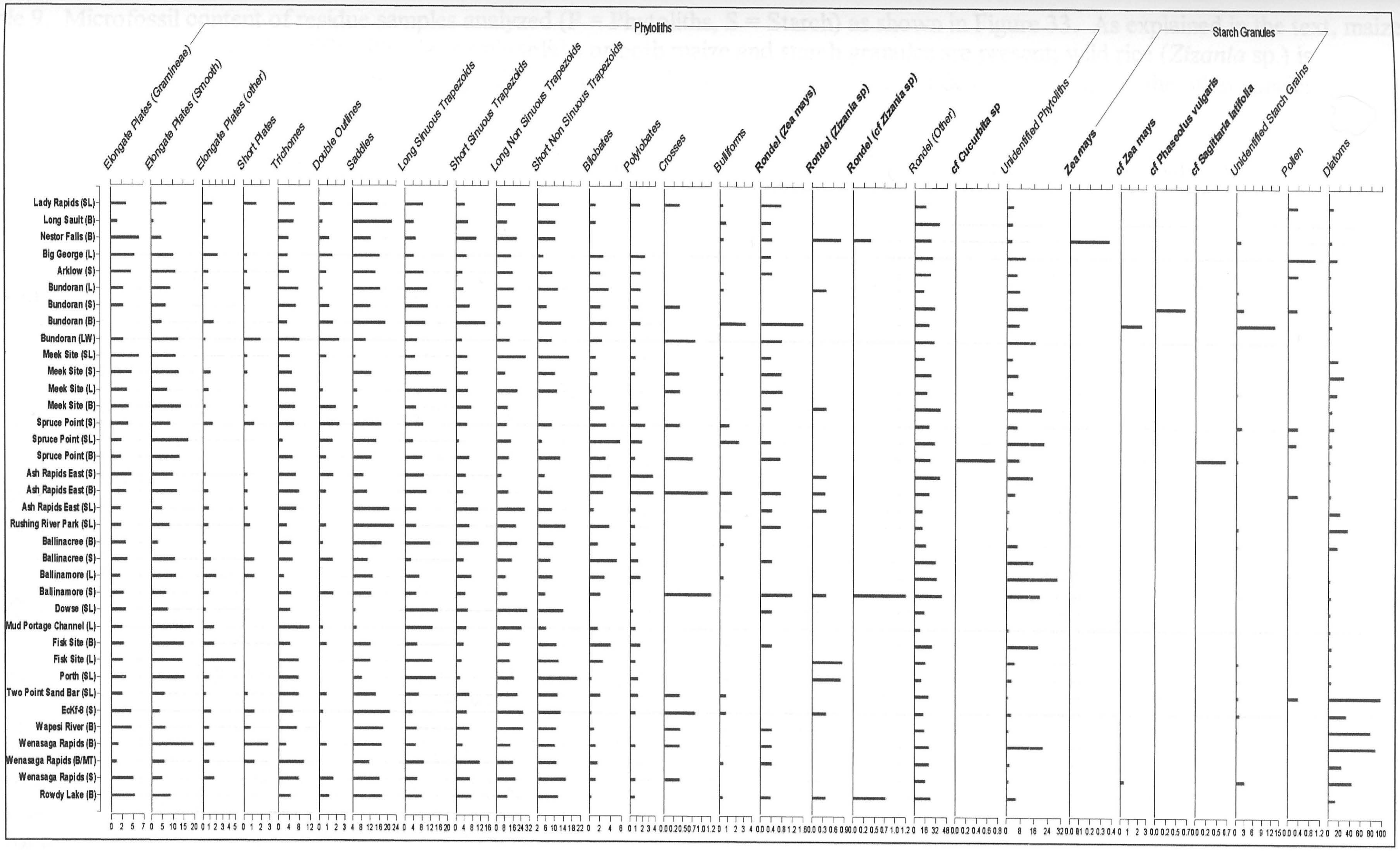

Figure 33. Microfossil data from carbonized food residues (L = Laurel, B = Blackduck, B/MT = Blackduck/Mixed Traits, S = Selkirk, SL = Sandy Lake, LW = Late Woodland).

Table 9. Microfossil content of residue samples analyzed (P = Phytoliths, S = Starch) as shown in Figure 33. As explained in the text, maize (Zea mays) is only positively identified if maize or phytoliths or both maize and starch granules are present; wild rice (*Zizania* sp.) is identified based on the presence of diagnostic phytoliths outlined in this study; a tentative identification is given for the other species.

Borden #	**Site Name**	**Pottery Type**	**Maize (*Zea mays*)**	**Wild Rice (*Zizania* sp.)**	**cf. Common Bean (*Phaseolus vulgaris*)**	**cf. Arrowhead (*Sagittaria latifolia*)**	**cf. Squash/Gourd (Cucurbita sp.)**
DcKc-1	**Lady Rapids**	**Sandy Lake**	P				
DdKm-1	**Long Sault**	**Blackduck**	P				
DgKl-3	**Nestor Falls**	**Blackduck**	P/S	P			
DiKp-3	**Big George**	**Laurel**	P				
DiKp-5	**Arklow**	**Selkirk**	P				
DjKn-5	**Bundoran**	**Laurel**		P			
DjKn-5	**Bundoran**	**Selkirk**			S		
DjKn-5	**Bundoran**	**Blackduck**	P/S				
DjKn-5	**Bundoran**	**Late Woodland**	P				
DjKp-3	**Meek Site**	**Sandy Lake**	P				
DjKp-3	**Meek Site**	**Selkirk**	P				
DjKp-3	**Meek Site**	**Laurel**	P				
DjKp-3	**Meek Site**	**Blackduck**	P	P			
DjKq-1	**Spruce Point**	**Selkirk**					
DjKq-1	**Spruce Point**	**Sandy Lake**	P				
DjKq-1	**Spruce Point**	**Blackduck**	P			S	P
DjKq-4	**Ash Rapids East**	**Selkirk**		P			
DjKq-4	**Ash Rapids East**	**Blackduck**	P	P			
DjKq-4	**Ash Rapids East**	**Sandy Lake**	P	P			
DkKn-1	**Rushing River Park**	**Sandy Lake**	P				
DkKp-8	**Ballinacree**	**Blackduck**					
DkKp-8	**Ballinacree**	**Selkirk**	P				
DkKp-9	**Ballinamore**	**Laurel**					

Table 9. (Continued).

DkKp-9	Ballinamore	Selkirk	P	P			
DkKr-2	Dowse	Sandy Lake	P				
DkKr-4	Mud Portage Channel	Laurel					
DlKp-1	Fisk Site	Blackduck	P				
DlKp-1	Fisk Site	Laurel		P			
EaLa-2	Porth	Sandy Lake		P			
EcKc-4	Two Point Sand Bar	Sandy Lake					
EcKf-8	N/A	Selkirk		P			
EdKb-1	Wapesi River	Blackduck	P				
EdKh-1	Wenasaga Rapids	Blackduck	P				
EdKh-1	Wenasaga Rapids	Blackduck or Mixed Traits	P				
EdKh-1	Wenasaga Rapids	Selkirk	S				
EdKo-6	Rowdy Lake	Blackduck	P	P			

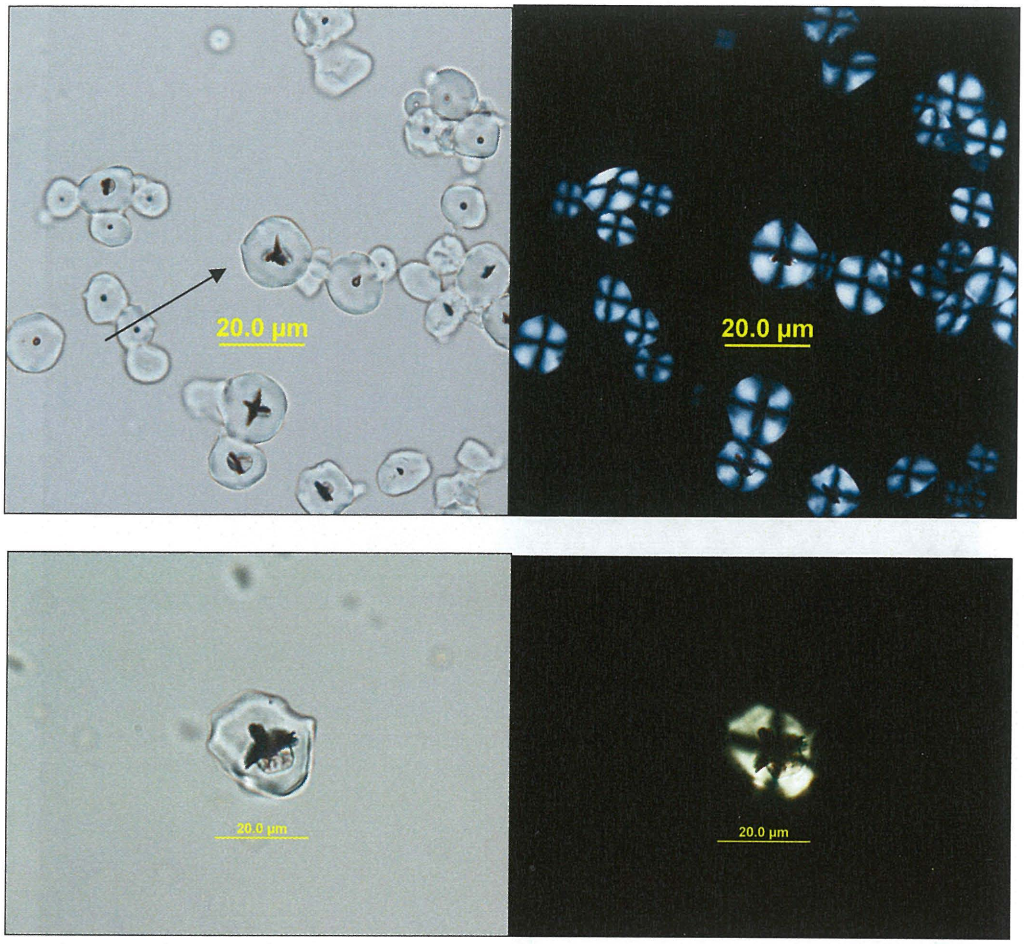

Figure 34. Photomicrographs of comparative maize (*Zea mays*) (top row = plane polarized light (PPL) (left), cross-polarized light (XPL) (right)) and archaeological maize (*Zea mays)* starch from a Blackduck vessel at the Nestor Falls site (bottom row = plane polarized light (PPL) (left), cross-polarized light (XPL) (right)).

Figure 35. Microscopic images of wild rice rondel phytoliths from comparative (top) and from carbonized food residue from a Blackduck vessel from the Meek site (bottom). Both are examples of short, four-spiked rondels with three indentations, one in the centre of the base, and one on either side.

Only six samples had evidence of both maize and wild rice rondels: four Blackduck vessels, one from Nestor Falls, one from the Meek, one from Ash Rapids East, and another from Rowdy Lake site; one Selkirk vessel from Ballinamore site; and one Sandy Lake vessel from Ash Rapids East site. A starch granule classified as maize was also found at the Nestor Falls site. Interestingly, maize and wild rice were recovered in both Sandy Lake and Blackduck ceramics at the Ash Rapids East site.

A single scalloped phytolith diagnostic of possible squash (*Cucurbita* sp.) or wild gourd (Piperno et al., 2000) was recovered from a Blackduck vessel from the Spruce Point site (Figure 36). The phytolith is characteristic of squashes or gourds; however it is small and may represents a wild gourd since domesticated varieties tend to have larger phytoliths. However, it may not be from *Cucurbita* sp. since fungal spores from *Tilletia* (Pascoe, 2005), may mimic scalloped phytoliths.

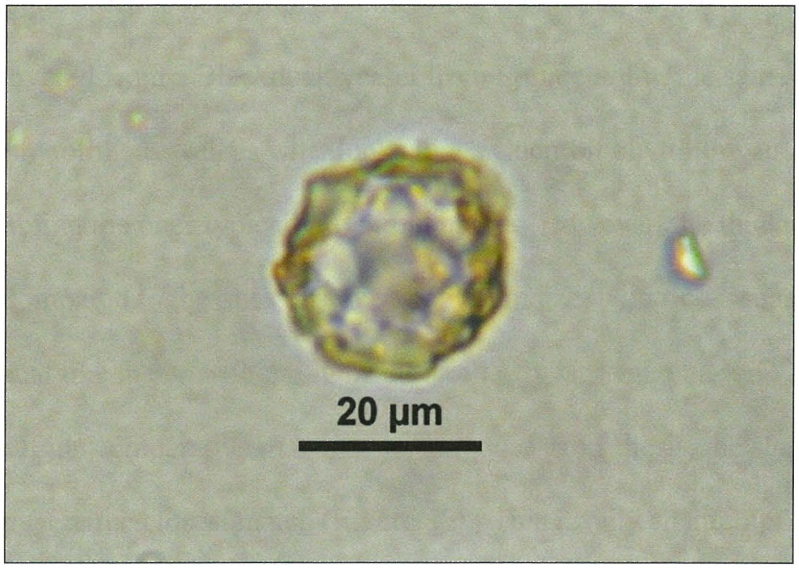

Figure 36. Possible squash/gourd (*Cucurbit* sp.) phytolith from a Blackduck vessel at the Spruce Point site.

Pollen grains (Figure 37) and diatoms were also found in the carbonized food residues. Pollen counts were very low (>1%) compared to the diatoms, which ranged from 1 to 97% of the total assemblage.

Figure 37. Pollen grains from a Laurel vessel at the Big George site.

Starch granules resembling the ones described for the common bean (Hoover and Ratnayake, 2002; Su et al., 1998) were recovered from one sample, a Selkirk vessel from the Bundoran site (Figure 38). Although they match the starch granules found in beans, more work needs to be done in this area to determine whether or not wild plants produce “confuser types”. A starch grain recovered from a Blackduck vessel from Spruce Point, the same vessel where a diagnostic maize phytolith, as well as what looks like a Cucurbit phytolith was recovered, has a “Y” fissure, resembling the ones typically found in maize. However, the thickness of this starch grain is very low compared to the ones observed both in maize, wild rice, squash or even beans. The grain is elliptical like the ones found in beans and fairly large and has an “X” shaped extinction cross. Of the comparative materials examined for this thesis, the starch grains from *Sagittaria latifolia* were the closest match (Figure 39). This is only an attempt to classify this starch grain, although further research is needed to verify this assumption.

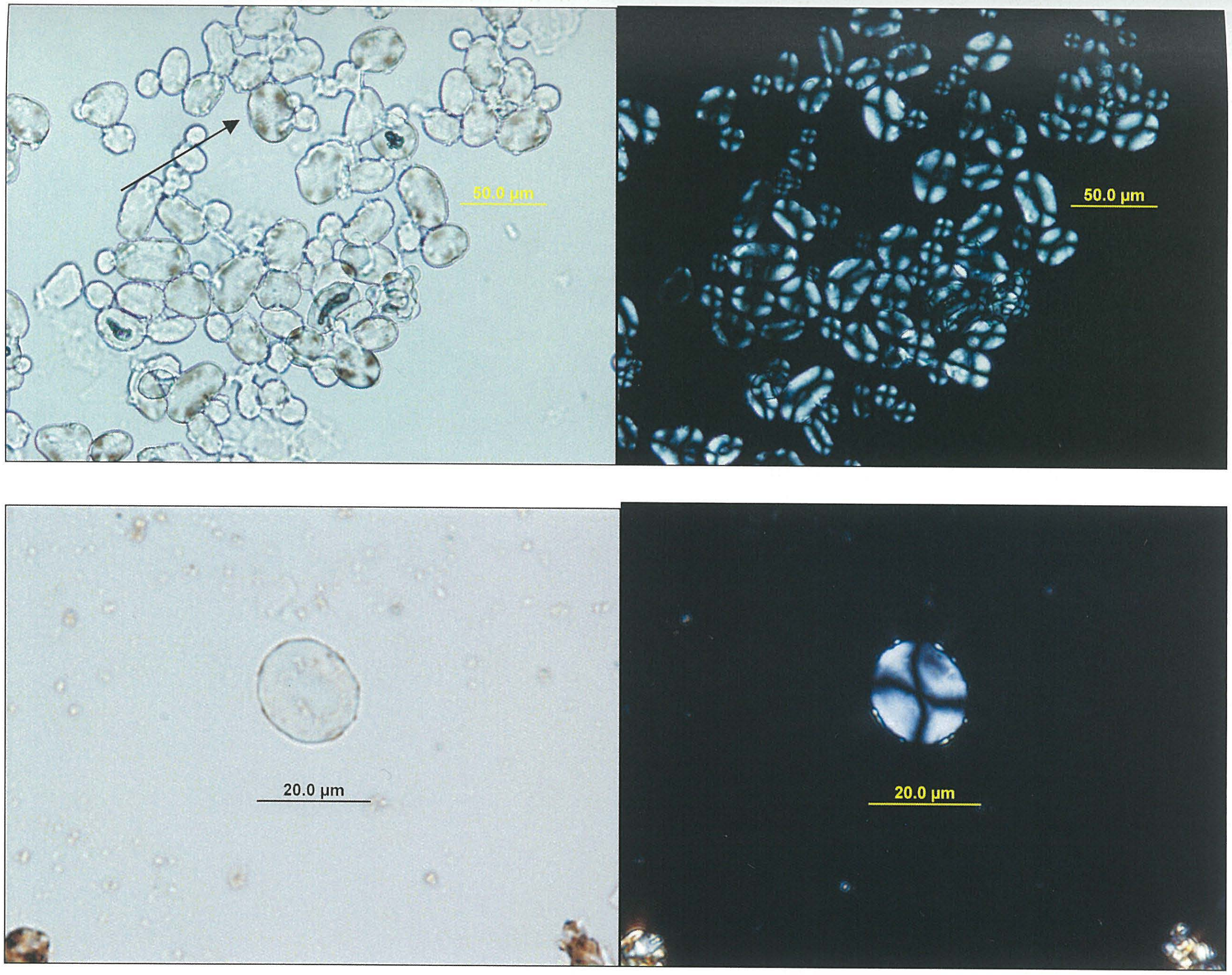

Figure 38. Microscopic images of comparative bean (*Phaseolus vulgaris*) (top row = plane polarized light (PPL) (left), cross-polarized light (XPL) (right)) and possible bean (*Phaseolus vulgaris*) starch from a Selkirk vessel at the Bundoran site (bottom row = plane polarized light (PPL) (left), cross-polarized light (XPL) (right)).

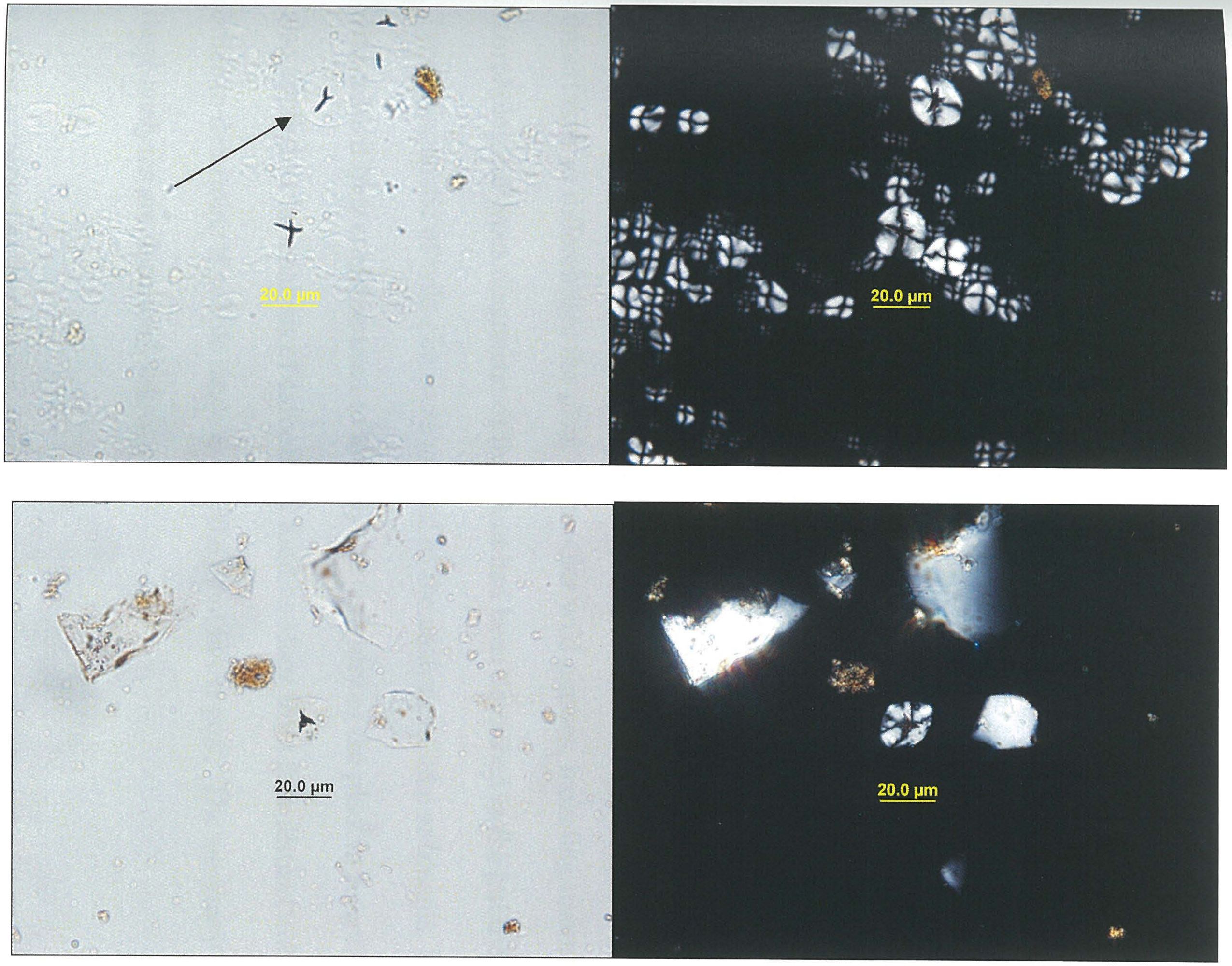

Figure 39. Microscopic images of comparative arrowhead (*Sagittaria latifolia*) (top row = plane polarized light (PPL) (left), cross-polarized light (XPL) (right)) and possible arrowhead (*Sagittaria latifolia)* starch from a Blackduck vessel at the Spruce Point site (bottom row = plane polarized light (PPL) (left), cross-polarized light (XPL) (right)).

CHAPTER 8: DISCUSSION AND CONCLUSIONS

8.1. INTRODUCTION

Paleoethnobotanical research at or near archaeological sites in the study area is almost non-existent. Due to highly acidic soils, bones do not tend to survive, let alone plant material, and the only faunal information available comes from a few sites where preservation was accidentally enhanced (Arthurs, 1986b; Wright, 1967). Furthermore, floatation techniques have not been attempted at many sites (Spiedel, 1989) and, therefore very few macrofossils are available to reconstruct the plant portion of the prehistoric diet.

It has been suggested that the high number of archaeological sites in the area is likely due to the appearance of wild rice; however, there is virtually no evidence supporting this other than speculations about population sizes, the appearance of mounds at sites, and the correlation of their locations with modern wild rice stands (Rajnovich, 1984).

To learn more about the importance of wild rice in the area, a phytolith analysis was undertaken to differentiate the plant from other wild grasses, including maize, especially since no morphological types diagnostic of this plant had been described in the published literature. Types diagnostic of wild rice were applied to the analysis of lake sediments, in order to determine if they could be used to identify the antiquity of the plant in future research, and were also applied to the analysis of carbonized food residues from four distinct cultural groups in order to determine if people made use of the plant in the past. The summary and conclusions of these analyses are described below.

8.2. DIAGNOSTIC RONDEL TYPES PRODUCED IN WILD RICE AND MAIZE

In order to reconstruct the plant component of the diet of prehistoric peoples, a taxonomy was developed in order to distinguish wild rice phytoltihs from those of wild grasses (Appendix B). Based on the taxonomy devised as a part of this project, eight rondel phytolith types that are only found in wild rice are distinguished, from which four are preferred since they do not have types with similar features occurring in other plants. Tall and short four-spiked rondels with 1 and 3 indentations are diagnostic of wild rice (Figure 27, Table 8). Based on the plants observed in the study area, there were no rondel types that mimicked the appearance of those described as being diagnostic of maize (Bozarth, 1993a).

Statistical analysis of the data supports the idea that wild rice and maize have very different rondel assemblages. Wild rice produces high values of rondel types with projections (>50%) and indented bases (>70%) compared to maize which has high values of rondel types with no projection (~ 50%) and entire bases (~80%). Statistically, the rondel assemblages of wild rice and maize can be distinguished from each other as noted by Hart et al. (2003) and Thompson et al. (1994).

Wild rice produces a distinct assemblage of rondel types, some with features that have only been observed in a few wild grasses, most of which do not tend to grow in or near aquatic settings, therefore the use of wild rice assemblages might be a good indicator of this plant, especially in lake sediments. Because maize tends to cluster statistically with wild grasses which also have high values of types with no projections and entire bases; it might be difficult to distinguish it by its rondel assemblage. Since phytolith sizes can vary in a plants depending on climate and the environmental conditions in which they are grown in (Ball and Brotherson, 1992; Brown, 1984; Piperno, 2006), using size measurements might not be enough to distinguish maize from assemblages where wild grasses are suspected. A cautious approach would be to use size measurements in combination with diagnostic morphological types when an assemblage is looked at.

8.3. WILD RICE RONDELS IDENTIFIED IN LAKE SEDIMENT

Diagnostic types for wild rice were utilized to detect the presence of the plant in lake sediments from Lulu Lake near Kenora, Ontario. The sediment was taken from a part of the lake where wild rice grows today, and therefore the uniform sapropel collected in the core is thought to represent a recent deposition (Figure 40). Influx of sediment from other sources is most likely not an issue since Rice Bay in Lulu Lake is somewhat sheltered from some of the major inlets (Figure 40). As discussed in chapter 7, rondels characteristic of wild rice were recovered from two of the four samples; however, only three rondels characteristic of wild rice is represented by this. Phytoliths were obscured in the sediment by high diatom content, which might explain the small numbers of identified rondels. Although the values are small, presence of wild rice can still be identified in lake sediments by its diagnostic rondel phytolith types.

Diatoms in the sediment might also have an effect in the recovery of diagnostic types of wild rice rondels. Other factors that could affect the recovery of diagnostic types are the influx of other wild grasses into the sediment and the consumption of the wild rice grains, both by humans and animals. Rondels in general, were also recovered in large quantities (>18%) in all four samples. Since wild rice is the only grass growing in the middle of the bay at Lulu Lake, there is a good chance that most of the rondels counted in the sediment originated from this plant. However, this assumption is challenged by the fact that some of the rondels found in the sediment have concave bases. Because concave bases do not occur in great quantities in wild rice, it is likely that the source of concave base rondels in the lake sediment comes from species, which tend to grow in or near the same habitat as wild rice.

The role of wave action in removing phytoliths from shoreline settings, and depositing them deeper into the basin, especially in shallow lakes like Lulu might have an impact on the phytolith assemblage represented. As mentioned above, concave base rondels, which might have originated from certain grasses that live in the water or along the shore are represented in the sediment, the role of wind and wave action might have brought some of these plants deeper into the lake where wild rice grows. Wild rice can also get uprooted and moved around, and therefore might not get deposited where it grows. Due to wind and wave action, the plant could have been moved to the shore once it is floating above the water. Not all types of rondels are representative of wild rice and therefore the few diagnostic types used to identify the plant, represents only a percentage of the total population.

Since the sample size in this analysis is small, it is difficult to know if the problems associated with the recovery of diagnostic phytoliths are really an issue or not. Also, all types of phytoliths were counted as part of the analysis; if the focus was kept only on the rondels, it may increase the sample counts, thus yielding better results. However, rondel types diagnostic of wild rice can be recovered from lake sediment, which is very important since in combination with pollen analysis, wild rice phytoliths are sure to be a powerful tool in the reconstruction of its vegetation history.

8.4. WILD RICE AND MAIZE IDENTIFIED IN CARBONIZED FOOD RESIDUES: IMPLICATIONS

Multiple types of microfossils were recovered from the carbonized food residues. Phytoliths and starch granules were the main focus of this analysis; however, pollen and diatoms were also recovered. The presence of pollen grains in the carbonized residues most likely occurred by accident, since many pollen grains are ubiquitous in the atmosphere and would easily get into the residue either during its use or after it was buried in the soil.

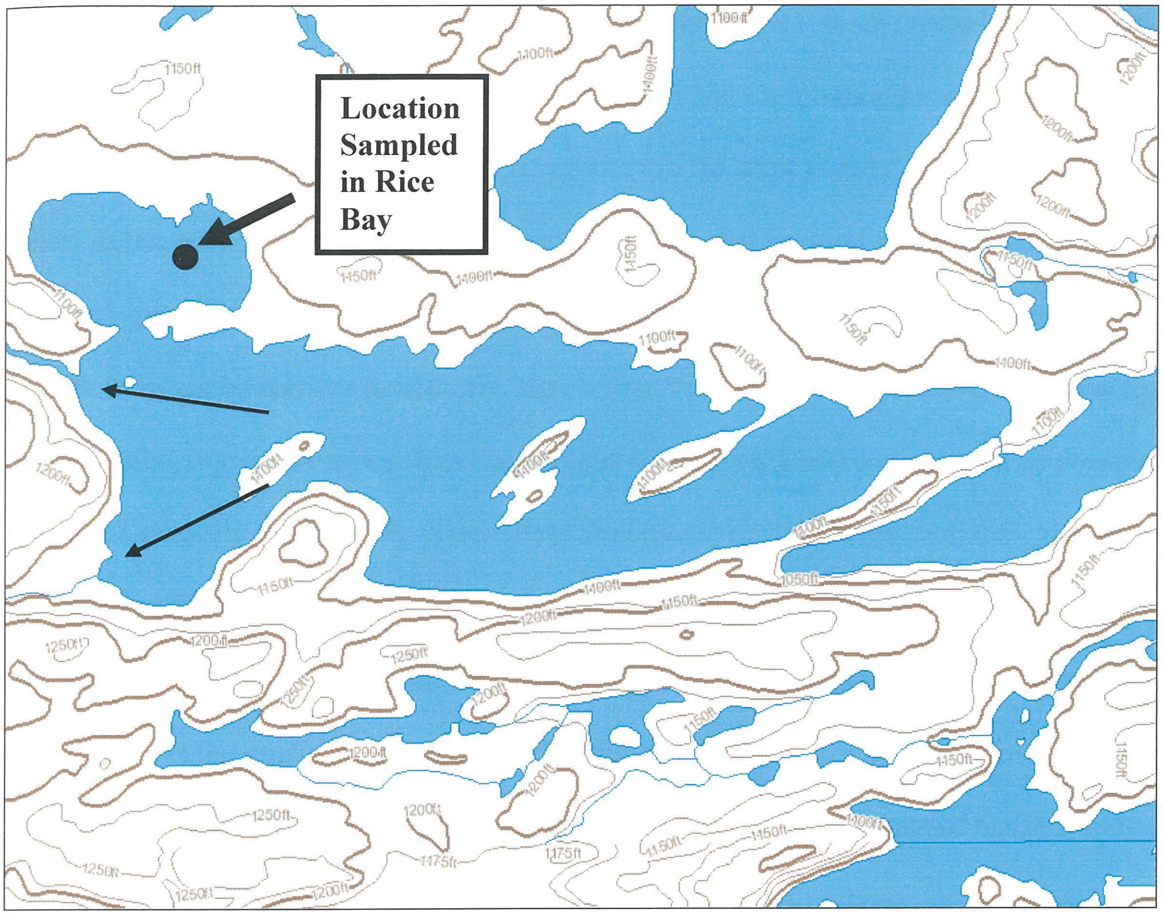

Figure 40. Location sampled for sediment in Lulu Lake in relation to inlets (see arrows).

Very few starch granules were recovered from the carbonized food residues. Processing methods of both maize and wild rice may have been a factor in the addition or loss of starch grains in the residue. Starch granules might not have been released into the pot if the kernels or seeds were not crushed or broken (i.e., when the outer layer of the shell of the seed is opened). Starch grains might have also been lost due to boiling and frothing of the food in the pot (Hart et al., 2007). Because there is little “set-back” of the starch grain after cooling from being cooked at high temperatures, as described by Lorenz (1981), wild rice and maize starch may not appear in archaeological food residues when looked at under cross polarized light. Also, mature wild rice grains in the comparative samples tended to have little starch concentrations to begin with. Postdepositional factors such as soil property (acidity), bacteria, and mechanical breakdown of larger grains (Haslam, 2004) could have affected the amount of starch grains left in the residues. The acidity of Boreal Forest soil tends to be very high and even bones do not tend to survive, therefore it is likely that acids might leach into the residue after burial and destroy the starch grains. If the pots were not cleaned after use it is likely that bacteria would have had an effect on the starch granules. The mechanical breakdown of larger grains by crushing of the kernels to make flour might be another reason why they do not tend to survive. If maize flour was traded in the study area, one could expect that bacteria and mechanical breakdown would be two reasons why starch grains are destroyed. Given these limitations, phytoliths are crutial for maize and wild rice identification.

Maize (*Zea mays*) and possible squash (*Phaseolus vulgaris*) starch grains were classified using criteria in the published literature, and based on observation, a starch grains was tentatively identified as possible arrowhead (*Sagittaria latifolia*). The small amounts of maize starch recovered suggests that either they did not extract the starch from the kernels by crushing to make flour or other meals, or that they did not rely much on maize and only acquired small amounts through trade or grew small amounts near their villages. Possible bean starch granules were recovered from a single Selkirk vessel at the Bundoran site. Beans have not been identified this far north during the Late Woodland period; however, the Selkirk phase runs right until the end of the precontact period, which at this time Middle Missouri and Oneota groups south of the study area are known to have made use of this cultigen. The recovery of a starch granule similar to those found in the tubers of arrowheads (*Sagittaria latifolia*) from a Blackduck vessel from the Spruce Point site is interesting. Although additional work is needed to verify this identification, tubers of arrowhead were an excellent source of food used by Native peoples during the historic period. Coincidently, the same vessel contained both maize and what seems to be a squash or wild gourd phytoltih. Squashes and wild gourds have been naturalized in North America for a very long time, and therefore it does not seem that unlikely that it would have been consumed by people who made Blackduck pottery.

In general, rondels made up a large quantity of the phytoliths recovered in carbonized food residues. Since wild rice and maize are edible and are big producers of rondels, it is likely that they are the source of the rondels; however, only diagnostic rondels are considered to represent the presence of one or both plants. It is possible that by measuring the other rondels recovered and applying the square-chord distance statistics of Hart et al. (2003, 2007) and Thompson et al. (1994) studies, that one might attribute them to either wild rice or maize (see Hart et al., 2003, 2007). However, one must approach this carefully since it is equally possible that the rondels of other grasses that overlap in size might make their way into the residues through contamination or burial in soil, even if they are edible species or not.

Wild rice and maize have been identified together in the residues of several vessels; it is interesting that both plants are found in the residues of all four cultures in the study area. It is also interesting that maize is found in Laurel, since many people believe that wild rice was the reason for the spread of this culture; however, in light of this new evidence this assumption can be challenged. Of course, wild rice might have had a role in the spread of Laurel since wild rice rondels were also found in at least two of the Laurel vessels analysed; however, this is difficult to address at this point.

At the Meek site, the presence of maize was identified in Laurel, Blackduck, Selkirk, and Sandy Lake vessels, suggesting a long lasting use of maize at this site. The site has evidence of a Laurel house structure, and is thought to also have been a Selkirk village and ceremonial centre with a mass burial associated with Selkirk, there is also what appears to be a Blackduck mound at this site. An Oneota rim was also found in the assemblage at this site, this might be an indication of where the maize and certain cultural patterns could have originated.

The Meek site, as with other places where houses and/or mounds have been found such as the Long Sault, Lady Rapids, Spruce Point, Ballynacree, Bundoran, and Fisk sites seem to fit into a similar pattern. They all provided evidence of maize, and, in some samples, wild rice. This seems to make sense since they are all major sites where people would have gathered together to exploit wild rice and fish and other aquatic resources, also they are located along major water routes. Therefore it may be possible that these are sites where people would have practiced horticulture either on site or in nearby areas, especially since maize was cultivated, at least in a few areas on "Garden Islands" in Lake of the Woods during the early postcontact period (Moodie and Kaye, 1969). At the very least, these sites would have been areas where trade would have occurred.

Interestingly, other sites such as Rowdy Lake, Nestor Falls, and Ash Rapids East where fishing is though to have been the major occupation also display evidence of people consuming maize and wild rice together, especially in the Blackduck component of all three sites. Both maize and wild rice are also found together in a Blackduck and Sandy Lake vessel from the Ash Rapids East site. This makes sense in light of the fact that they are also found at other sites where wild rice and maize are present in areas outside of their range. It is possible that people at these sites were involved in other activities throughout the summer between the fall and spring seasons to grow maize and then collect wild rice later in the summer before the fall. Another possibility is that they might have acquired the maize through trade for fish or other products.

The identification of grasses other than wild rice and maize in carbonized food residues or lake sediment may also seem possible based on the assemblages of concave and other types of rondels. Since very few concave rondels (<1%) were observed in wild rice and maize, concave rondels or assemblages of such types found in the carbonized food residues might represent the use of wild grasses; however, it could also represent contamination from the soil, or could have been unintentionally introduced into the pot by people when it was in use. However, as noted in chapter 6, people did make use of the seeds and other parts of some grasses to make flour or other products and therefore it seems likely to expect that there might be evidence of these plants in the residue.

This is the first time maize and wild rice are reported from prehistoric archaeological sites in northwestern Ontario. It is likely that since most sites are on known water travel routes, that maize might have been traded into the area; horticulture might have been possible as in the early Historic period where some rivers and islands were also used for horticulture. However, evidence is lacking at this time to support this point.

8.5 CONCLUSIONS

Some researchers (Darbyshire and Aiken, 1986; Hart et al., 2003, 2007; Terrell and Wergin, 1981; Thompson and Mulholland, 1994; Thompson et al., 2004) have focused on the morphology and size ratios of wild rice rondels; however, none of them have established any diagnostic types. Based on the results presented in this thesis, it is apparent that wild rice produces several types of diagnostic rondels. This might be due to the fact that wild rice is a big producer of rondels in general. Diagnostic types identified appear in both *Zizania palustris* and *Zizania aquatica*, and therefore more works needs to be done to see if these two plants can be separated, but for now they can be identified as *Zizania* sp. Furthermore, analysis of comparative grasses confirmed that rondel types identified as being diagnostic of maize can be used in the study area to determine the presence of maize since plants that produced "confuser" types were not found.

The use of phytoliths in sediments has gained more and more importance recently (Lentfer and Boyd, 1998, 1999, 2000; Parr, 2002; Zhao and Pearsall, 1998). The methods devised in this study show that plants such as wild rice can be identified and distinguished from other plants. Due to time constraints, the purpose of analyzing sediments for phytoliths was to determine whether or not the rondel types identified for wild rice would be present in the lake sediment. Although only a few examples of wild rice rondels were recovered from the lake sediment, the presence of wild rice in the sediment is still confirmed. Since pollen grains from wild rice can vary and have overlaps with other wild species (Lee et al., 2004), although it can be positively identified with the use of a scanning electron microscope, the use of wild rice rondels could be a good cost and time effective proxy to remedy this problem. Therefore, pollen analysis in combination with phytolith analysis would be most useful in reconstructing the plant history of wild rice.

It has been traditionally assumed that climatic conditions limited maize (*Zea mays*) production to the Dakotas and perhaps southern Minnesota, with limited further northward diffusion. The prehistoric northern limits of maize, has been recently reassessed (Boyd et al 2006, 2008), with the widespread discovery of maize micro-botonical evidence on Plains Woodland pottery in southern Manitoba and in the adjacent Boreal Forest (Boyd et al., 2008). The widespread appearance of maize (*Zea mays*) in Laurel, Blackduck, Sandy Lake, and Selkirk pots in the Lake of the Woods and surrounding area seems to support the observation that the use of maize is not localized but widespread. Perhaps these people maintained small garden plots in suitable places, as suggested by Schneider (2002) for the Northeastern Plains, or that canoe-based water transportation offered some degree of efficiency for trade.

During the Late Archaic-Early Woodland period, there are many cultural changes that occur. Sites appear to become large (at least from what is seen based on the ceramic recoveries), more complex, and cultural interactions and exchanges become more apparent. It is thought to reflect changes due to the adoption of wild rice or perhaps maize. The results presented in this work, suggests that, the consumption of maize was widespread in the Lake of the Woods and surrounding areas during the prehistoric period. The presence of wild rice does not appear to be as widespread; however this could be due to a sample bias or because of food preparation procedures which might have removed the parts containing the phytoliths from the grain.

It is interesting that microbotanical evidence of maize (*Zea mays*) appears in the carbonized food residues of Middle and Late Woodland pottery, especially where wild rice (*Zizania palustris*) was expected to be the major plant harvested based on site location or cultural affiliation. Perhaps it was not present at the time of human occupation of the area, or that maize (*Zea mays*) is more readily preserved and observed in the carbonized food residues compared to wild rice (*Zizania palustris*) (depending on method of preparation). In some samples, especially Blackduck, wild rice and maize are found together, suggesting a reliance on a mixed economy, which might have been related to the population surge during the Late Woodland period. During this period other Late Woodland societies are also making a shift towards maize as a staple, people in the study area might have tried maize horticulture or acquired maize through trade, while still keeping their focus on an economy based on wild rice, hunting, and fishing with the use of various aquatic resources available, which allows for better predictability in case of crop failure.

Many archaeologists believe that wild rice (*Zizania palustris*) sustained higher population densities during the Woodland period in the Upper Great Lakes region since there is a big jump in site numbers between the Archaic and Woodland period. Based on the results presented in this thesis, wild rice does not appear to be a major staple in the study area since it is only found in a few samples. However, we can not rule out the possibility that wild rice (*Zizania* sp.) may just not be as visible in the food. During parching and winnowing the husk of the wild rice kernels tends to be removed; therefore if none of these plant parts remain with the grains they will not appear in the residues, especially since wild rice rondels are in the husk. Maize is usually taken off of the cob by rubbing or cutting the kernels off, since the grains are tightly packed together it is likely that the cupules surrounding the kernel (which contains the rondels) will come off with it, it is not necessary to clean these out for consumption and therefore have a likely chance of being incorporated into the residue. However, it is also possible that the samples analyzed were not the most likely candidates to have contained wild rice phytoliths.

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APPENDIX A. COMPARATIVE PLANT SPECIES EXAMINED

Table 10. Comparative plant specimens examined; location of sample taken and microfossil type extracted.

Scientific Name	Common Name	Sample Type	Description
Agrostis scabra	Rough bentgrass	Phytolith	Inflorescence/Leaves
Alopecurus aequalis	Shortawn foxtail	Phytolith	Inflorescence/Leaves
Amelanchier alnifolia	Saskatoon	Starch	Fruit
Andropogon gerardii	Big bluestem	Phytolith	Inflorescence/Leaves
Beckmannia syzigachne	Slough grass	Phytolith	Inflorescence/Leaves
Bromus ciliatus	Fringed brome	Phytolith	Inflorescence/Leaves
Calamagrostis canadensis	Canada bluejoint	Phytolith	Inflorescence/Leaves
Carex aquatilis	Water sedge	Phytolith/Starch	Inflorescence/Leaves/Seeds
Carex aurea	Golden sedge	Phytolith	Inflorescence/Leaves
Carex crinita	Fringed sedge	Phytolith	Inflorescence/Leaves
Carex rostrata	Beaked sedge	Phytolith	Inflorescence/Leaves
Carex viridula	Green sedge	Phytolith	Inflorescence/Leaves
Cinna latifolia	Drooping woodreed	Phytolith	Inflorescence/Leaves
Cucurbita sp.	Squash/pumpkin	Phytolith/Starch	Rinds/Stem/Leaves/Fruit/Seeds
Danthonia spicata	Poverty grass	Phytolith	Inflorescence/Leaves
Deschampsia cespitosa	Tufted hairgrass	Phytolith	Inflorescence/Leaves
Dichanthelium acuminatum	Hairy panicgrass	Phytolith	Inflorescence/Leaves
Distichlis spicata	Salt grass, spike grass	Phytolith	Inflorescence/Leaves
Dulichium arundinaceum	Three-way sedge	Phytolith	Inflorescence/Leaves
Eleocharis palustris	Creeping spike-rush	Phytolith	Inflorescence/Leaves/Stem
Elymus canadensis	Canada wildrye	Phytolith	Inflorescence
Eragrostis hypnoides	Teel lovegrass	Phytolith	Inflorescence/Leaves
Festuca rubra	Red fescue	Phytolith	Inflorescence/Leaves
Glyceria grandis	Tall manna grass	Phytolith	Inflorescence/Leaves
Graphephorum melicoides	Melic oats	Phytolith	Inflorescence/Leaves
Helianthus annuus	Common sunflower	Starch	Seed
Hesperostipa comata	Speargrass	Phytolith	Inflorescence/Leaves
Hordeum jubatum	Foxtail barley	Phytolith	Inflorescence/Leaves
Juncus balticus	Wire rush	Phytolith	Inflorescence/Leaves/Stem

Table 10. (Continued).

Juncus bufonius	Toad rush	Phytolith	Inflorescence/Leaves
Juncus nodosus	Knotted rush	Phytolith	Inflorescence/Leaves/Stem
Koeleria macrantha	Junegrass	Phytolith	Inflorescence/Leaves
Leersia oryzoides	Rice cutgrass	Phytolith	Inflorescence/Leaves
Luzula multiflora	Common woodrush	Phytolith	Inflorescence/Leaves
Milium effusum L.	Millet grass	Phytolith	Inflorescence/Leaves
Muhlenbergia glomerata	Marsh muhly	Phytolith	Inflorescence/Leaves
Nuphar variegatum	Yellow pond lily	Starch	Seed/Tuber
Oryzopsis asperifolia	Rough-leaved ricegrass	Phytolith	Inflorescence/Leaves
Oryzopsis canadensis	Canadian ricegrass	Phytolith	Inflorescence/Leaves
Oryzopsis pungens	Northern rice grass	Phytolith	Inflorescence/Leaves
Panicum capillare	Witchgrass	Phytolith	Inflorescence/Leaves
Pascopyrum smithii	Western wheatgrass	Phytolith	Inflorescence/Leaves
Phalaris arundinacea	Reed canary grass	Phytolith/Starch	Inflorescence/Leaves/Seeds
Phaseolus vulgaris	Red kidney bean	Phytolith/Starch	Seed/Pod
Phragmites australis	Common reed	Phytolith	Inflorescence/Leaves
Poa palustris	Fowl meadow grass	Phytolith	Inflorescence/Leaves
Psoralea esculenta	Breadroot	Starch	Starch from tuber
Rubus idaeus	American red raspberry	Starch	Fruit
Sagittaria latifolia	Broad-leaved arrowhead	Phytolith/Starch	Leaves/Tuber/Rhizome
Schedonorus pratensis	Meadow fescue	Phytolith	Inflorescence/Leaves
Schizachne purpurascens	False melic	Phytolith	Inflorescence/Leaves
Scirpus microcarpus	Small-fruited bulrush	Phytolith	Inflorescence/Leaves
Scirpus validus	Softstem bulrush	Phytolith/Starch	Inflorescence/Leaves/Stem/Seed/Rhizome
Sphenopholis intermedia	Prairie wedgegrass	Phytolith	Inflorescence/Leaves
Sporobolus neglectus	Puffsheath dropseed	Phytolith	Inflorescence/Leaves
Torreyochloa pallida	Fernald's false mannagrass	Phytolith	Inflorescence/Leaves
Trisetum spicatum	Spike trisetum	Phytolith	Inflorescence/Leaves
Typha latifolia	Cattail	Phytolith/Starch	Roots/Leaves/Stem/Rhizome
Zea mays	Maize	Phytolith/Starch	Inflorescence/Leaves/Cob/Seed
Zizania aquatica	Wild rice	Phytolith/Starch	Inflorescence/Leaves/Seeds
Zizania palustris	Northern wild rice	Phytolith/Starch	Inflorescence/Leaves/Stem/Seed

APPENDIX B: RONDEL CLASSIFICATION KEY

Definitions

Composite: Tops composed of varying combinations of projections such as waves, spikes, flat or rounded projections.

Concave base: The complete base of the rondel is concave upwards towards the top of the rondel, it is not an indentation.

Concave and indented base: Base is concave upwards towards the top but also notched.

Concave sides: Sides are concave, therefore curving towards the centre of the rondel.

Crest: The upward portion of a wave.

Crosses: Phytoliths with four indentations in the base (indentations are across from each other in the shape of a cross) are considered as crosses.

Entire base: Base is flat, no concavity or indentations.

Flat top rondel: Top is a flat or nearly flat, straight line from one side to the other, tops may appear slightly curved because a rondel is cylindrical in three dimensions.

Indented base: Base is not concave but is notched or indented.

Irregular rondel: Asymmetrical and/or combining elements of other tops such as bumps or spikes, straight and concave sides or other.

Projections: Spike, horn, wave and mixed (spikes, horns or waves) or other (flat or rounded (convex) projections).

Rondel: A phytolith form, body is a short cylinder to truncated or bevelled cone; outline of base approximately oval to circular or other curved shape (base may have concave or flat segments but general outline is curved shape); top is a flat to slightly concave or convex face or elevated ridge(s) (Mulholland and Rapp, 1992:80).

Ruffle-top rondel: Described by Bozarth (1993a). Occurs in genus *Zea*. Base is a rondel that is oval to circular in outline. Rondel must be longer than it is tall. Edges of top are ruffled or undulating, filmy in maize, more heavily silicified in teosinte. The top does not have any acute or sharply angled edges. Tops distinctly not with spikes. Top is flat and ephemeral. View from top is outline of ruffled top crossing more heavily silicified circular outline of the rondel base. Top is often larger than the base.

Short rondel: Height of the phytolith is shorter than the width of the base.

Spike: A sharp-pointed projection, usually tapers to a point; rounded spikes must be taller than wide, if length is not greater than the width then to qualify as a spike, point must be sharp.

Straight sides: Sides of the rondel are a straight line, parallel and roughly perpendicular to the base.

Tabular top: Top is similar in size and shape as base (Mulholland and Rapp, 1992:85).

Tall rondel: Height of the phytolith is longer than the width of the base; or the height of the rondel equals the width of the base.

Triangular spike: Spike with two straight sides, like the two sides of the top of a triangle.

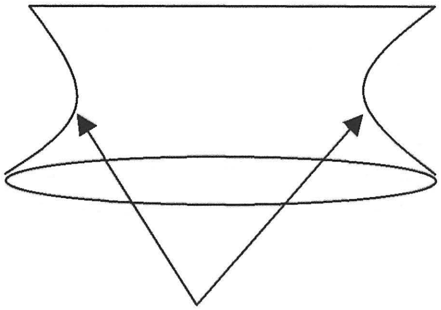
Trichome: Phytoliths that are cone shaped from the base to the top, the two sides of the phytolith come together from the base to form the top; sides tend to be straight or convex.

Trough: The downward portion of a wave.

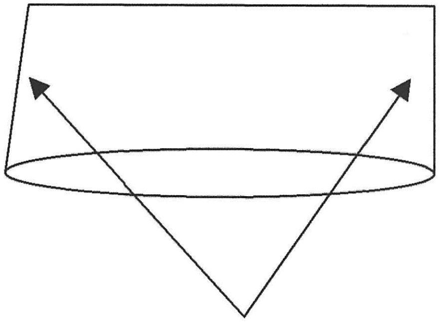
Wave: An outward curve, or one of a series of such curves, in a surface or line; undulation (composed of crest and troughs); a wave is also a shape or outline having successive curves or an undulating line or streak or a pattern formed by such lines.

Wavy-top rondel: Described by Bozarth (1993a). Base a rondel (circular to oval in shape, entire), flat, not concave. Base must be longer than the body is high/tall; top is a single, complete wave that is equal to or less than the length of the rondel base. Edges of the top and bottom are not ruffled. Convergence of the sides forms the top, which is a single, undulating wave. Peaks or sides of wave do not form horns or spikes. Top may be narrow, almost keel-like, and flimsy. Rectangular bases, bilobate bases, and saddle bases are excluded from this type. Occurs only in maize.

Entire base Rondel

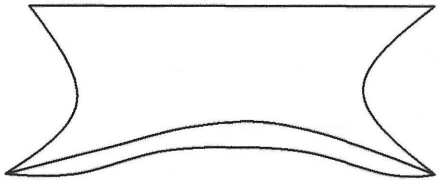


Concave Sides

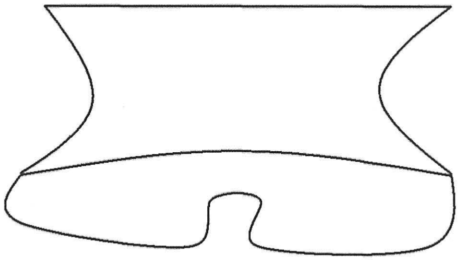


Straight Sides

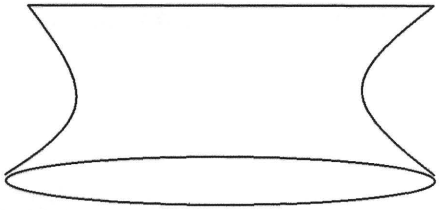
Concave Base Rondel



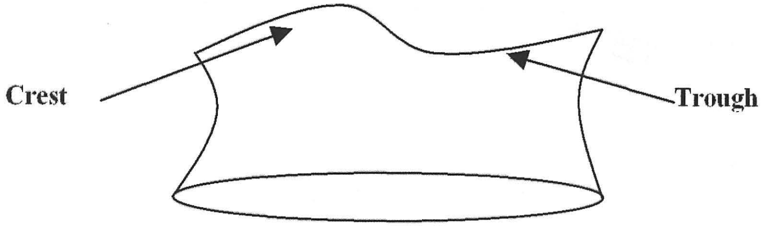
Indented Base Rondel



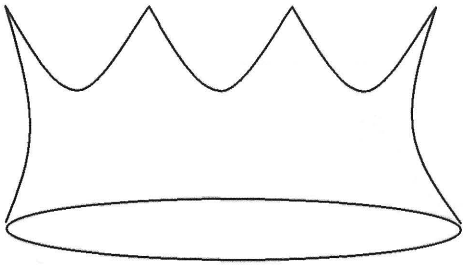
Flat Top Rondel



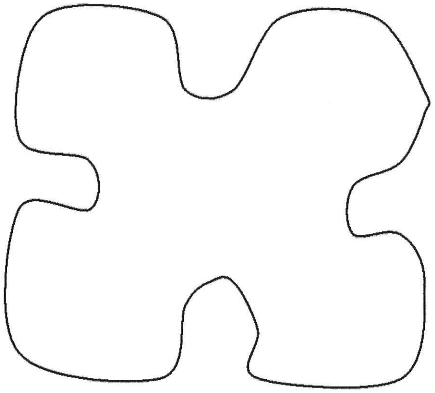
Wavy-Top Rondel



Spiked Rondel

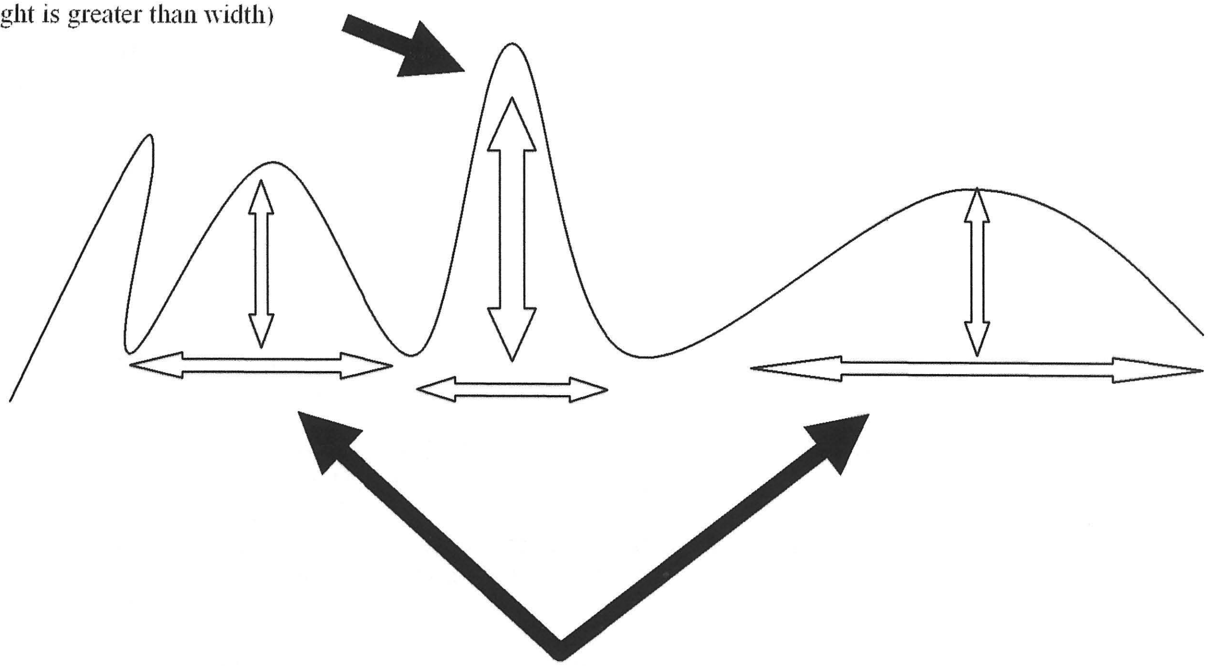


Cross base



Cross when viewed from the Base (4 indentations, 2 pairs across from each other).

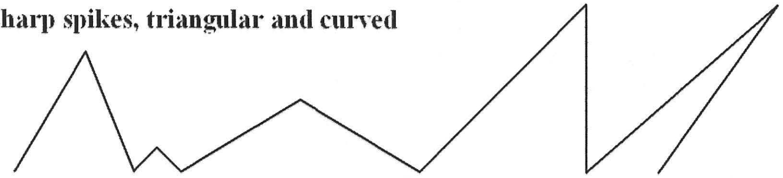
Rounded spikes

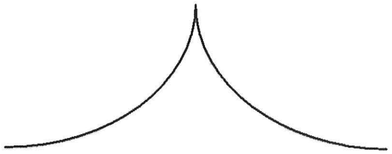


Spike (height is greater than width)

Wave (width is greater than height), not spikes

Various sharp spikes, triangular and curved





Rondels

1. No projections on top

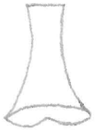
- **A. Flat top (top is flat or nearly so, no spikes are present)**
  - I. Entire base
    - a. Concave sides
      - i. Tall
      - ii. Short
    - b. Straight sides
      - i. Tall
      - ii. Short
  - II. Indented base
    - a. Concave sides
      - i. One indentation
        - a. Tall, indentation is in the middle of the base
        - b. Short
          - i. Indentation in the centre, or near the centre of the base
          - ii. Indentation on the side of the base
      - ii. Three indentations, short
        - a. One indentation on either side of the base and one in the centre
        - b. Three indentations in the centre of the base
    - b. Straight sides
      - i. One indentation, short
        - a. Indentation in the centre of the base
        - b. Indentation on the side of the base
      - ii. Two indentations, short
        - a. One indentation on either side of the base
        - b. Two indentations on the same side of the base
    - c. Irregular sides (one straight or convex and one concave side), short
      - i. One indentation
      - ii. Multiple indentations
  - III. Concave base, sides are concave and slightly bulging outwards (convex), short


I.A.I.a.i.


I.A.I.a.ii.


I.A.I.b.i.


I.A.I.b.ii.

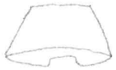

I.A.II.a.i.a.


I.A.II.a.i.b.i.


I.A.II.a.i.b.ii.


I.A.II.a.ii.a.


I.A.II.a.ii.b.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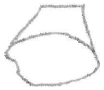
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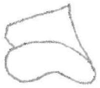
I.A.II.b.ii.a.


I.A.II.b.ii.b.


I.A.II.c.i.

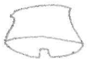

I.A.II.c.ii.


I.A.III.

1. No projections on top

- **B. Rounded top (slightly convex)**
    - I. Indented base
        - a. Concave sides, one indentation in the centre of the base
            - i. Tall
            - ii. Short
        - b. Irregular sides (straight, convex or/and concave sides)
            - i. One indentation in the middle of the base, short
            - ii. Two indentations, towards the sides of the base
                - a. Tall
                - b. Short, one spike on the side
            - iii. Multiple indentations, short
    - II. Concave base, short, concave sides
- **C. Three sided top**
    - I. Entire base, concave sides, short
    - II. Indented base, two indentations towards the side of the base, short


1.B.I.a.i.

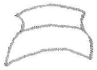

1.B.I.a.ii.


1.B.I.b.i.


1.B.I.b.ii.a.


1.B.I.b.ii.b.


1.B.I.b.iii.


1.B.II.


1.C.I.


1.C.II.

2. Projections on top (non spiked)

- **A. Flat projection**
  - **I. "Type 1" (projections are flat or nearly so, oriented horizontally)**
    - a. One projection, entire base, one concave and one straight side, tall
    - b. Two projections
      - i. Entire base, concave sides, short
      - ii. Indented base
        - a. Concave sides
          - i. Tall, one indentation in the centre of the base
          - ii. Short, two indentations, one indentation off-centre in the base and one on the side
        - b. Straight sides, one indentation in the centre of the base, short
      - iii. Concave base, irregular, short
    - c. Three projections, one indentation in the centre of the base, concave sides, short
  - **II. "Type 2" (projections are flat or nearly so, oriented diagonally)**
    - a. Entire base, concave sides
      - i. Tall
      - ii. Short
    - b. Indented base, concave sides
      - i. One indentation in the centre of the base
        - a. Tall
        - b. Short
      - ii. Two indentations, one indentation off-centre in the base and one on the side, short
- **B. Rounded projections**
  - I. Two indentations, irregular sides, one indentation near the centre of the base and one on the side, short
  - II. Three indentations, one in the centre and one on either side, irregular sides, short


2.A.I.a.
2.A.I.b.i.
2.A.I.b.ii.a.i.
2.A.I.b.ii.a.ii.
2.A.I.b.ii.b.
2.A.I.b.iii.
2.A.I.c.
2.A.II.a.i.
2.A.II.a.ii.
2.A.II.b.i.a.
2.A.II.b.i.b.
2.A.II.b.ii.
2.B.I.
2.B.II.

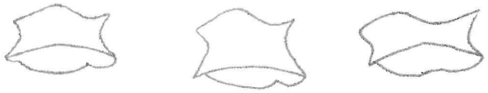
2. Projections on top (non spiked)

- **C. Wavy top**
  - **I. "Type 1" (one crest and one trough, symmetrical or nearly symmetrical)**
    - a. Entire base (*Zea mays*), concave sides, short
    - b. Indented base
      - i. Concave sides
        - a. One indentation
          - i. Tall, one indentation in the centre of the base
          - ii. Short, one indentation towards the side of the base
        - b. Two indentations, one indentation in or near the centre of the base and one on the side of the base, short
        - c. Three indentations or more, short
      - ii. Irregular sides (one straight and one concave side), short
        - a. One indentation, the indentation is near the side of the base
        - b. Two indentations, both indentations are in or near the middle of the base
    - c. Concave base
      - i. Concave sides, short
      - ii. Irregular sides (one convex and one concave side), short
  - **II. "Type 2" Ruffle top rondel (*Zea mays*);** short, entire base, concave sides, filmy top with multiple waves (see definition for Ruffle Top rondel)
  - **III. "Type 3" (one trough, one crest and one trough, symmetrical)**
    - a. Entire base, concave sides, short
    - b. Indented base, one indentation is in the centre of the base, concave sides, short
    - c. Concave base, concave sides, tall
  - **IV. "Type 4" (one trough, one crest and one trough, off-centred)**
    - a. Entire base
      - i. Concave sides, short
      - ii. Irregular sides (one straight and one concave side), short
    - b. Indented base
      - i. Concave sides, one indentation in or near the centre of the base, short
      - ii. Irregular sides (one straight and one concave side), short, two indentations on one side of the base


2.C.I.a.

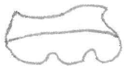

2.C.I.b.i.a.i.


2.C.I.b.i.a.ii.


2.C.I.b.i.b.


2.C.I.b.i.c.


2.C.I.b.ii.a.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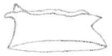
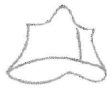
2.C.I.c.i.


2.C.I.c.ii.


2.C.II.


2.C.III.a.


2.C.III.b.


2.C.III.c.


2.C.IV.a.i.

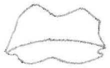

2.C.IV.a.ii.


2.C.IV.b.i.

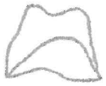

2.C.IV.b.ii.

2. Projections on top (non spiked)

- **C. Wavy top**
  - **V. "Type 5" (two crests on either side of a trough, one complete wave and one partial one)**
    - a. Symmetrical top, irregular sides (convex, straight and/or concave sides)
      - i. Indented base, three indentations, one in the centre and one on either side of the base, short
      - ii. Concave base, short
    - b. Assymetrical top, irregular indentations, concave sides, short
  - **VI. "Type 6" (two complete waves, with a crest and trough)**
    - a. Indented base, one indentation on the side of the base, concave sides, short
    - b. Concave base, irregular placement of the waves on the top
      - i. Concave sides, short
      - ii. Irregular sides (one straight and one concave side), short
  - **VII. "Type 7" (two complete waves, and one partial one, three crests with two troughs in between)**
  - a. Entire base, concave sides
    - i. Tall
    - ii. Short
  - b. Indented base, two indentations near the sides of the base, concave sides, short
  - c. Concave base, concave sides, irregular placement of the waves on the top, short
  - **VIII. "Type 8" (three complete waves and one partial one, four crests with three troughs in between)**
    - a. Entire base, concave sides, assymetrical placement of the waves on the top, short
    - b. Indented base, concave sides, two indentations near the centre of the base, assymetrical placement of the waves on the top, tall
- **D Projections on top (composite of waves and flat projections);** short rondel with three projections: one wave, one trough and one wave with a flat projection on the top with concave sides and two indentations, one near the centre of the base and one on the side of the base.



2.C.V.a.i.



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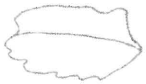
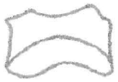


2.C.V.b.

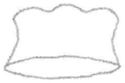
2.C.VI.a.

2.C.VI.b.i.

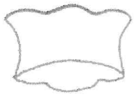


2.C.VI.b.ii.

2.C.VII.a.i.

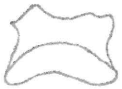


2.C.VII.a.ii.



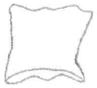
2.C.VII.b.

2.C.VII.c.

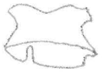


2.C.VIII.a

2.C.VIII.b.



2.D.



3. Projections on top (spiked)

- **A. One spike**
  - **I. “Type 1” (triangular spike)**
    - a. Entire base, concave sides, short
    - b. Indented base
      - i. Straight sides, indentation is in the centre of the base, short
      - ii. Irregular sides (concave and straight)
        - a. One indentation
          - i. Indentation in the middle of the base, tall
          - ii. Indentation on the side of the base, short and tall
        - b. Two indentations, short, one indentation in or near the centre and one on the side
        - c. Three indentations, one in the centre and one on either side, short
    - c. Concave base, straight sides, short
  - **II. “Type 2” (wavy spike, considered spike because it is taller than is wide)**
    - a. Entire base, concave sides, short
    - b. Indented base
      - i. One indentation, tall, concave sides
      - ii. Three indentations, concave and irregular sides, short
  - **III. “Type 3” (star shaped top)**
    - a. Entire base, concave sides
      - i. Tall
      - ii. Short
    - b. Indented base, concave sides, short
      - i. One indentation in the centre of the base
      - ii. One indentation on the side of the base
  - **IV. “Type 4” (flat top with spike on side of top)**
    - a. Entire base, irregular sides, tall
    - b. Indented base, three indentations; one in the centre and one on either side of the base, irregular sides (one straight and one concave side)
  - **V. “Type 5” (rounded top with spike on side of top)**
    - a. Entire base, tall, concave sides
    - b. Indented base, indentation is in the middle of the base, short, straight sides
  - **VI. “Type 6” (flat top with spike on top)**
    - a. Entire base, concave sides, short
    - b. Indented base
      - i. One indentation in the centre of the base, tall, concave sides
      - ii. Two indentations, concave sides, indentations are near the centre or on the sides of the base
        - a. Tall
        - b. Short
      - iii. Three indentations, one in the centre and one on either side of the base, concave sides, short

3.A.I.a.

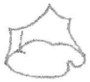
3.A.I.b.i.

3.A.I.b.ii.a.i.

3.A.I.b.ii.a.ii.

3.A.I.b.ii.b.

3.A.I.b.ii.c.



3.A.I.c.

3.A.II.a.

3.A.II.b.i.

3.A.II.b.ii.

3.A.III.a.i.

3.A.III.a.ii.

3.A.III.b.i.

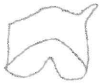
3.A.III.b.ii.

3.A.IV.a.

3.A.IV.b.

3.A.V.a.

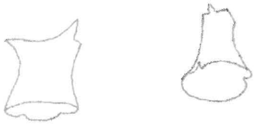
3.A.V.b.



3.A.VI.a.

3.A.VI.b.i.

3.A.VI.b.ii.a.



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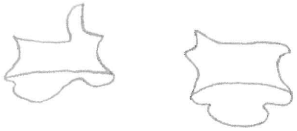
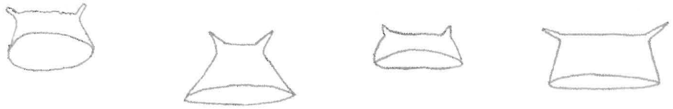


3.A.VI.b.iii.

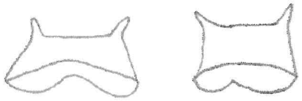
3. Projections on top (spiked)

- **B. Two spikes**
  - **I. "Type 1" (flat top with two spikes on either side, sides are all very straight or convex)**
    - a. Entire base, straight sides, short
    - b. Indented base, straight sides, short
      - i. One indentation in the centre of the base
      - ii. Two indentations in the centre of the base
      - iii. Three indentations, one in the centre and one on either side of the base
  - **II. "Type 2" (rounded top with two spikes on either side)**
    - a. Entire base, concave sides, short
    - b. Indented base
      - i. Concave sides, short, one indentation in the middle of the base
      - ii. Straight sides, one indentation on the side of the base, short
        - a. No projections on the sides of the rondels
        - b. Projections on the sides of the rondel
    - c. Concave and indented base, concave sides, short
  - **III. "Type 3" (crescent shaped spikes, almost flat on top, but stills tapers to a point)**
    - a. Entire base, concave sides
      - i. Tall
      - ii. Short
    - b. Indented base, concave sides, short
      - i. One indentation in the centre of the base
      - ii. Three indentations, one in the centre and one on either side of the base
    - c. Concave base, tall, concave sides

3.B.I.a.



3.B.I.b.i



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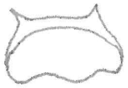

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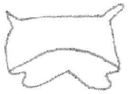
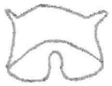


3.B.II.a.

3.B.II.b.i.



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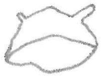

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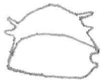
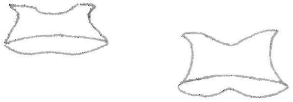


3.B.II.c.

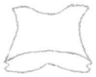
3.B.III.a.i.

3.B.III.a.ii.

3.B.III.b.i.



3.B.III.b.ii.



3.B.III.c.

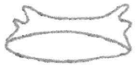
<u>3. Projections on top (spiked)</u>

- **B. Two spikes**
  - **IV. "Type 4" (sharp or rounded spikes on either side of the top)**
    - a. Entire base
      - i. Concave sides
        - a. Tall
        - b. Short
      - ii. Straight sides, short
      - iii. Irregular sides (one straight and one concave), short
    - b. Indented base
      - i. Concave sides
        - a. One indentation
          - i. Indentation in the middle of the base, concave sides
            - a. Tall
            - b. Short
          - ii. Indentation on the side of the base, tall, irregular sides
        - b. Two indentations, concave sides
          - i. Indentations on either side of the base, short
          - ii. Indentations in the middle of the base
            - a. Tall
            - b. Short
          - iii. One indentation in the middle and on the side of the base, short
        - c. Three indentations, concave sides
          - i. One indentation in the middle and one on either side
            - a. Tall
            - b. Short
          - ii. Indentations are on one side of the centre of the rondel base or on opposite sides of the centre and the side of the base, short
      - ii. Straight sides
        - a. One indentation in the centre of the base, short
        - b. Two indentations in the centre or sides of the base
          - i. Tall
          - ii. Short
    - c. Concave base
      - i. Concave sides
        - a. Tall
        - b. Short
      - ii. Straight sides, short
      - iii. Irregular sides, short

3.B.IV.a.i.a.

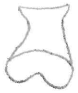
3.B.IV.a.i.b.

3.B.IV.a.ii.



3.B.IV.a.iii.

3.B.IV.b.i.a.i.a.



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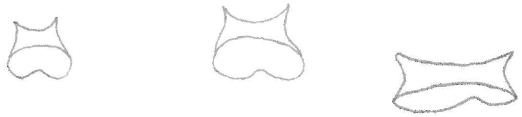
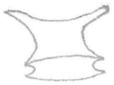


3.B.IV.b.i.a.ii.

3.B.IV.b.i.b.i.



3.B.IV.b.i.b.ii.a

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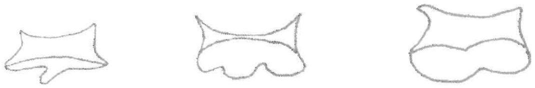

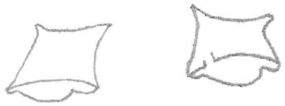

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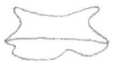
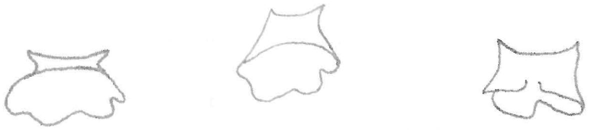


3.B.IV.b.i.c.i.a.

3.B.IV.b.i.c.i.b.

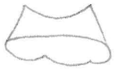
3.B.IV.b.i.c.ii.



3.B.IV.b.ii.a.

3.B.IV.b.ii.b.i.

3.B.IV.b.ii.b.ii.



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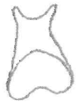


3.B.IV.c.i.b.

3.B.IV.c.ii.

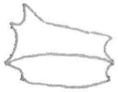
3.B.IV.c.iii.

3. Projections on top (spiked)

- **B. Two spikes**
    - **V. "Type 5" (one spike on top and another on the side of the top)**
        - a. Entire base, concave sides, short
        - b. Indented base, short
            - i. Concave sides, two indentations, one indentation on either side of the base
            - ii. Straight sides
                - a. One indentation, one indentation on the side of the base
                - b. Two indentations, one in the centre and one on the side of the base
    - **VI. "Type 6" (two spikes in the middle of the top)**
        - a. Entire base
            - i. Concave sides, short
            - ii. Straight sides, short
            - iii. Irregular sides
                - a. Tall
                - b. Short
        - b. Indented base, concave sides
            - i. One indentation in the centre of the base
            - ii. Two indentations, one indentation on either side of the base
        - c. Concave base, short
            - i. Concave sides
            - ii. Straight sides

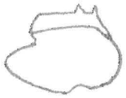
3.B.V.a.

3.B.V.b.i.



3.B.V.b.ii.a.

3.B.V.b.ii.b.



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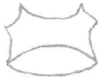
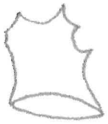
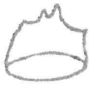


3.B.VI.a.ii.

3.B.VI.a.iii.a.



3.B.VI.a.iii.b.



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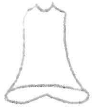
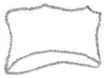


3.B.VI.b.ii.

3.B.VI.c.i.



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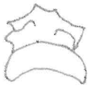


3. Projections on top (spiked)

- **C. Three spikes**
  - **I. “Type 1” (three spikes, sharp and rounded, tall and short spikes, symmetrical or nearly so)**
    - a. Entire base
      - i. Concave sides
        - a. Tall
        - b. Short
      - ii. Straight to convex sides
        - a. Tall
        - b. Short
    - b. Indented base
      - i. Concave sides
        - a. One indentation in the base
          - i. Indentation is in the middle of the base
            - a. Tall
            - b. Short
          - ii. Indentation is not in the middle of the base
            - a. Tall
            - b. Short
        - b. Two indentations in the base
          - i. One indentation on each side of the base
            - a. Tall
            - b. Short
          - ii. Indentations near the centre of the base or on the side and/or near centre of the base, tall
        - c. Three indentations in the base
          - i. Tall
          - ii. Short
        - d. Irregular indentations, short
      - ii. Straight to convex sides, one indentation in the centre of the base, short
    - c. Concave base, concave sides
      - i. Tall
      - ii. Short
    - d. Concave and indented base
      - i. No projections on the sides of the rondel, concave sides, short
      - ii. Spikes on the side of the rondel, irregular sides, short

3.C.I.a.i.a.

3.C.I.a.i.b.

3.C.I.a.ii.a.

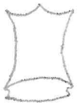
3.C.I.a.ii.b.

3.C.I.b.i.a.i.a.

3.C.I.b.i.a.i.b.

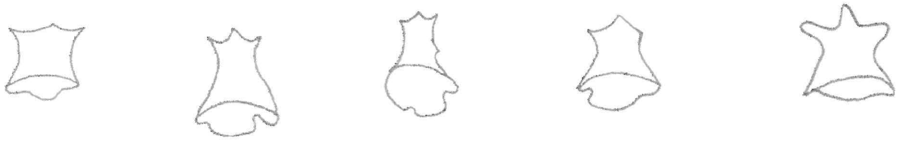
3.C.I.b.i.a.ii.a.

3.C.I.b.i.a.ii.b.



3.C.I.b.i.b.i.a.

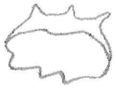
3.C.I.b.i.b.i.b.



3.C.I.b.i.b.ii.

3.C.I.b.i.c.i

3.C.I.b.i.c.ii.

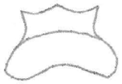


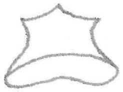
3.C.I.b.i.d.

3.C.I.b.ii.

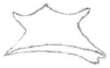
3.C.I.c.i.

3.C.I.c.ii.





3.C.I.d.i.



3.C.I.d.ii.

<u>3. Projections on top (spiked)</u>

- **C. Three spikes**
  - **II. "Type 2" (three spikes, sharp and rounded, tall and short spikes, middle spike is off-centred)**
    - a. Entire base, short, concave sides
    - b. Indented base, concave sides
      - i. One indentation in the base
        - a. Tall
        - b. Short
      - ii. Two indentations in the base, short
        - a. One indentation on either side of the base
        - b. One indentation in or near the middle of the base and one near or on the side of the base
    - c. Concave base
      - i. Concave sides, short
      - ii. Irregular sides (straight and concave), short
  - **III. "Type 3" (irregular spiked tops)**
    - a. Entire base, short
      - i. Concave sides
      - ii. Irregular sides
    - b. Indented base
      - i. One indentation in the centre or on the side of the base, short
        - a. Straight sides
        - b. Irregular sides
      - ii. Two indentations, tall, concave sides
      - iii. Three indentations, short, concave or irregular sides
    - c. Concave base, concave sides, short

3.C.II.a.

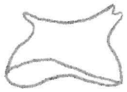
3.C.II.b.i.a.

3.C.II.b.i.b.

3.C.II.b.ii.a.

3.C.II.b.ii.b.

3.C.II.c.i.

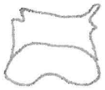


3.C.II.c.ii.

3.C.III.a.i.

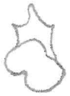
3.C.III.a.ii.

3.C.III.b.i.a.



3.C.III.b.i.b.

3.C.III.b.ii.



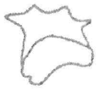
3.C.III.b.iii.

3.C.III.c.

3. Projections on top (spiked)

- **D. Four spikes**
  - **I. "Type 1" (spikes are sharp, top is symmetrical or nearly so)**
    - a. Entire base, concave sides
      - i. Tall
      - ii. Short
    - b. Indented base, concave sides
      - i. One indentation
        - a. Indentation in the middle of the base
          - i. Tall
          - ii. Short
        - b. Indentation on the side of the base
          - i. Tall
          - ii. Short
      - ii. Two indentations
        - a. Indentations on either side of the base
          - i. Tall
          - ii. Short
        - b. One indentation in the middle and one on the side of the base
      - iii. Three indentations
        - a. One indentation in the middle and one on each side of the base
          - i. Tall
          - ii. Short
  - b. Two indentations in the middle of the base on one side and another indentation in the centre of the base on the other
    - i. Tall
    - ii. Short
        - c. Irregular indentations, tall
    - c. Concave base, short
      - i. Concave sides
      - ii. Irregular sides
    - d. Concave and indented base, short

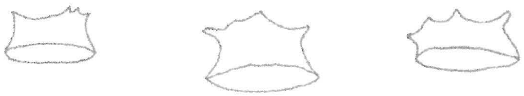

3.D.I.a.i.
3.D.I.a.ii.
3.D.I.b.i.a.i.
3.D.I.b.i.a.ii.
3.D.I.b.i.b.i.
3.D.I.b.i.b.ii.
3.D.I.b.ii.a.i.
3.D.I.b.ii.a.ii.
3.D.I.b.ii.b
3.D.I.b.iii.a.i.
3.D.I.b.iii.a.ii.
3.D.I.b.iii.b.i.
3.D.I.b.iii.b.ii.
3.D.I.b.iii.c
3.D.I.c.i.
3.D.I.c.ii.

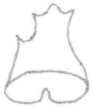


3.D.I.d.

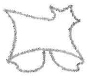
3. Projections on top (spiked)

- **D. Four spikes**
  - **II. "Type 2" (one spike is towards one side of the top while the other three are towards the opposite side)**
    - a. Entire base, concave sides, short
    - b. Indented base
      - i. One indentation, concave sides
        - a. Tall
        - b. Short
      - ii. Three indentations, concave sides, short
    - c. Concave base, concave sides, short
  - **III. "Type 3" (irregular spiked tops)**
    - a. Entire base
      - i. Concave sides, tall
      - ii. Irregular or straight sides, short
    - b. Indented base
      - i. One indentation
        - a. Tall, concave sides
        - b. Short, concave and straight sides
      - ii. Two indentations, concave sides
        - a. Tall
        - b. Short


3.D.II.a.


3.D.II.b.i.a.

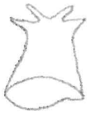

3.D.II.b.i.b.

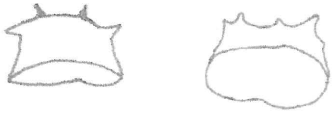

3.D.II.b.ii.


3.D.II.c.


3.D.III.a.i.


3.D.III.a.ii.


3.D.III.b.i.a.


3.D.III.b.i.b.


3.D.III.b.ii.a.

3.D.III.b.ii.b.

<u>3. Projections on top (spiked)</u>

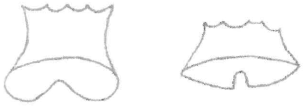
- **E. Five spikes**
  - **I. "Type 1" (spikes are sharp, top is symmetrical or nearly so)**
    - a. Entire base, concave sides
      - i. Tall
      - ii. Short
    - b. Indented base
      - i. One indentation, concave sides
        - a. Tall
        - b. Short
      - ii. Two indentations, concave sides
        - a. Tall
        - b. Short
      - iii. Three indentations
        - a. One indentation in the middle and one on each side of the base, concave sides
          - i. Tall
          - ii. Short
        - b. Irregular indentations, concave sides, tall
  - **II. "Type 2" (irregular spiked tops)**
    - a. Entire base
      - i. Tall, straight to concave sides
      - ii. Short, straight sides
    - b. Indented base
      - i. Concave sides
        - a. One indentation, concave sides
          - i. Tall, indentation is in the centre of the base
          - ii. Short, the indentation is in the centre or on the side of the base
        - b. Two indentations, one in the centre and one on the side of the base, concave sides, tall
      - ii. Straight sides, short, one indentation in the centre of the base
    - c. Concave base, concave sides, short
    - d. Concave and indented base, straight sides, short

3.E.I.a.i.

3.E.I.a.ii.

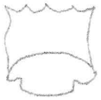
3.E.I.b.i.a.

3.E.I.b.i.b.



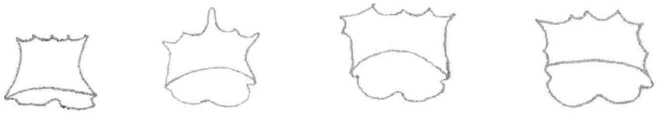
3.E.I.b.ii.a.

3.E.I.b.ii.b.

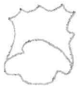


3.E.I.b.iii.a.i.

3.E.I.b.iii.a.ii.



3.E.I.b.iii.b.

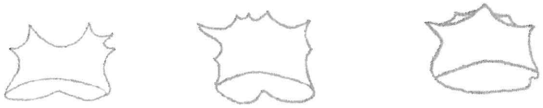


3.E.II.a.i.

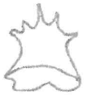
3.E.II.a.ii.

3.E.II.b.i.a.i.

3.E.II.b.i.a.i.

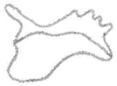


3.E.II.b.i.b.



3.E.II.b.ii.

3.E.II.c.



3.E.II.d.

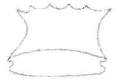
<u>3. Projections on top (spiked)</u>

- **F. Six spikes**
  - **I. "Type 1" (spikes are sharp, top is symmetrical or nearly so)**
    - a. Entire base
      - i. Concave sides, short
      - ii. Straight sides, short
    - b. Indented base
      - i. Concave sides
        - a. Two indentations, short
          - i. Indentations on either side of the base
          - ii. Indentations near centre of base
        - b. Three indentations, one in the centre and one on either side of the base, concave sides, short
      - ii. Straight sides
        - a. One indentation in the centre of the base, short
        - b. Two indentations, one on either side of the base, short
        - c. Three indentations, indentations are irregular, short
        - d. Four indentations, short
    - c. Concave base, concave sides, short
  - **II. "Type 2" (irregular spiked tops)**
    - a. Entire base, irregular sides, short
    - b. Indented base, three indentations, concave sides, short
    - c. Concave base, straight sides, short

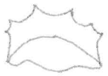
3.F.I.a.i.

3.F.I.a.ii.

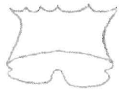
3.F.I.b.i.a.i.



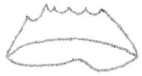
3.F.I.b.i.a.ii.



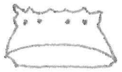
3.F.I.b.i.b.



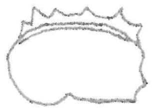
3.F.I.b.ii.a.



3.F.I.b.ii.b.



3.F.I.b.ii.c.



3.F.I.b.ii.d.

3.F.I.c.

3.F.II.a.

3.F.II.b.

3.F.II.c.

3. Projections on top (spiked)

- **G. Seven spikes**
  - **I. “Type 1” (spikes are sharp, top is symmetrical or nearly so)**
    - a. Entire base
      - i. Concave sides, tall
      - ii. Straight sides, short
    - b. Indented base, three indentations, one in the centre and one on either side, concave sides
  - **II. “Type 2” (irregular spiked tops)**
    - a. Entire base, short, concave sides
    - b. Indented base, three irregular indentations, irregular sides, short
- **H. Eight spikes;** concave sides, short, one indentation in the centre of the base
- **I. Nine spikes;** concave base, straight sides, short

3.G.I.a.i.

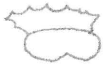
3.G.I.a.ii.

3.G.I.b.

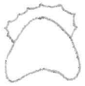
3.G.II.a.

3.G.II.b.

3.H.



3.I

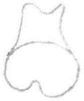


4. Projections on top (composite of spikes and waves)

- **A. Two projections**
  - **I. "Type 1" (one crest and one trough with a spike on one side)**
    - a. Entire base
      - i. Concave sides, tall
      - ii. Irregular sides (one concave and one straight side), short
    - b. Indented base
      - i. Concave sides
        - a. Tall, one indentation in the centre of the base
        - b. Short, one indentation in the centre of the base
      - ii. Irregular sides (one concave and one straight side), tall, two indentations one on each side of the centre of the base.
  - **II. "Type 2" (one trough, one crest and one trough with one spike on the side)**
    - a. Entire base, concave sides, short
    - b. Indented base
      - i. One indentation in the centre of the base, short, irregular sides (one concave and one straight side)
      - ii. Multiple indentations, short, irregular sides
    - c. Concave base, concave sides, short


4.A.I.a.i


4.A.I.a.ii.

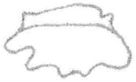

4.A.I.b.i.a.

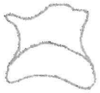

4.A.I.b.i.b.


4.A.I.b.ii.


4.A.II.a.


4.A.II.b.i.


4.A.II.b.ii.


4.A.II.c.

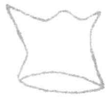
4. Projections on top (composite of spikes and waves)

B. Three projections

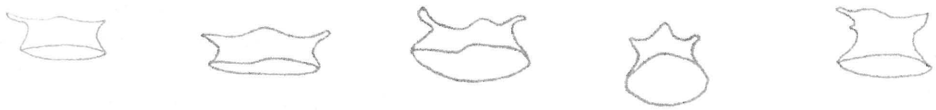
I. "Type 1" (one spike on each side of the top with one wave in the centre, one trough, one crest and one trough)

- a. Entire base, concave sides
  - i. Tall
  - ii. Short
- b. Indented base
  - i. One indentation, concave sides
    - a. Tall
    - b. Short
  - ii. Two indentations, tall, concave sides
  - iii. Three indentations, short, concave sides
- c. Concave base, short, irregular sides (straight, concave or convex)

4.B.I.a.i.

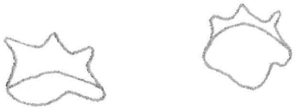


4.B.I.a.ii.

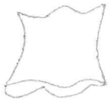


4.B.I.b.i.a.

4.B.I.b.i.b.



4.B.I.b.ii.



4.B.I.b.iii.

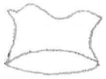
4.B.I.c.

4. Projections on top (composite of spikes and waves)

- **B. Three projections**
  - **II. "Type 2" (two waves one on the side of the top, one in the middle and a spike on the other side of the top)**
    - a. Entire base, concave sides
      - i. Tall
      - ii. Short
    - b. Indented base, concave sides, indentations on either side of the base or near the sides
      - i. Tall
      - ii. Short
    - c. Concave base, concave sides
  - **III. "Type 3" (two spikes, one in the middle and one on the side of the top, and a wave on the other side of the top)**
    - a. Entire base, concave sides, tall
    - b. Indented base
      - i. Tall, one indentation on either side of the base or one indentation in the centre of the base and one on the side, concave sides
      - ii. Short, one indentation on either side of the base, irregular sides (one straight and one concave)
    - c. Concave base, concave sides, short
  - **IV. "Type 4" (a spike with a wave on top on the same side with one spike on the other side)**
    - a. Entire base, short, concave sides
    - b. Indented base, two indentations near the sides of the base, short, concave sides

4.B.II.a.i.

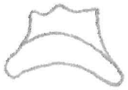
4.B.II.a.ii.



4.B.II.b.i.

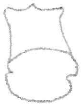
4.B.II.b.ii.

4.B.II.c.



4.B.III.a.

4.B.III.b.i



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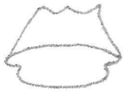

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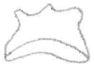
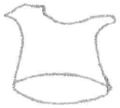
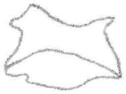


4.B.IV.a.



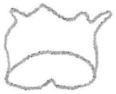


4.B.IV.b.

4. Projections on top (composite of spikes and waves)

- **C. Four projections**
  - **I. "Type 1" (one spike on either side of the top with two waves in the centre)**
    - a. Entire base, concave sides, short
    - b. Indented base, short
      - i. One indentation, the indentation is in the centre of the base, irregular sides
      - ii. Two indentations, concave sides, one indentation in the centre of the base and one on the side
    - c. Concave base, concave sides, short
  - **II. "Type 2" (Three spikes, one on the side of the top and two on the other with a wave in between)**
    - a. Concave sides, short
      - i. One indentation in the centre of the base
      - ii. Two indentations near the centre of the base
    - b. Irregular sides
      - i. One indentation in the centre of the base, short, sides are convex
      - ii. Three indentations, one in the centre of the base and one on either side, tall, one straight and one concave side
  - **III. "Type 3" (three waves followed by a spike on the side)**
    - a. Entire base, irregular sides, short
    - b. Indented base, short, concave sides
      - i. One indentation in the centre of the base
      - ii. Two indentations near the centre of the base
    - c. Concave base, short, concave sides
  - **IV. "Type 4" (other combinations of spikes and waves)**
    - a. Entire base, irregular sides, short
    - b. Indented base, irregular indentations and sides, short
    - c. Concave base, straight sides, short


4.C.I.a.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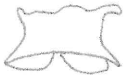
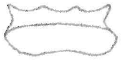

4.C.I.b.ii.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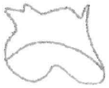
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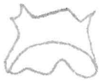
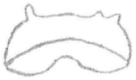
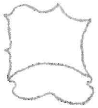
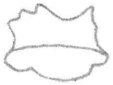

4.C.II.a.ii.


4.C.II.b.i.


4.C.II.b.ii.


4.C.III.a.


4.C.III.b.i.


4.C.III.b.ii.


4.C.III.c.


4.C.IV.a.


4.C.IV.b.


4.C.IV.c.

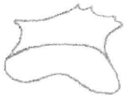
4. Projections on top (composite of spikes and waves)

D. Five projections

- I. Entire base, short
  - a. Concave sides
  - b. Straight sides
- II. Indented base, short
  - a. One indentation in the centre of the base
  - b. Two indentations, one on either side of the base
  - c. Three indentations, one in the centre and one on either side of the base or two in the centre on one side and one on the other side of the centre of the base
- III. Concave base, short
  - a. Concave sides
  - b. Irregular sides
- IV. Concave and indented base, short

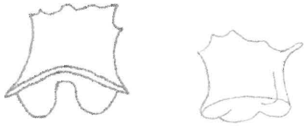
4.D.I.a.

4.D.I.b.

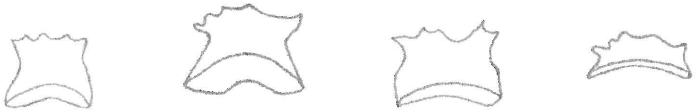


4.D.II.a.

4.D.II.b.

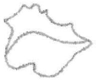


4.D.II.c.

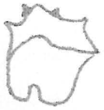


4.D.III.a.

4.D.III.b.



4.D.IV.



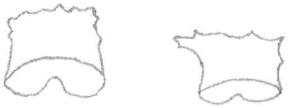
4. Projections on top (composite of spikes and waves)

- **E. Six projections**
  - I. Entire base, concave sides, short
  - II. Indented base
    - a. Indentation in the centre of the base, irregular sides, short
    - b. Indentation on the side of the base, straight sides, short
  - III. Concave base, concave sides, short
- **F. Seven projections;** concave sides, short, indented base, two indentations one on either side of the base
- **G. Eight projections;** concave sides, short, entire base
- **H. Nine projections;** concave sides, short, entire base
- **I. Ten projections;** irregular sides (one straight and one concave), short, three indentations, one in the centre and one on either side of the base

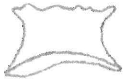
5. Projections on top (composite of flat and spiked projections)

- **A. Two projections**
  - I. Entire base, concave sides, short
  - II. Indented base
- a. Concave sides
      - i. One indentation, concave sides
        - a. Indentation in the middle of the base
          - i. Tall
          - ii. Short
        - b. Indentation on the side of the base
      - ii. Two indentations, concave sides, short
      - iii. Three indentations, concave sides, short
      - iv. Multiple indentations, concave sides, short
    - b. Straight sides, one indentation on the side of the base, short
    - c. Irregular sides (one straight and one concave), one indentation on the side of the base, short
  - III. Concave base, irregular sides, short

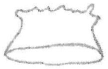

4.E.I.

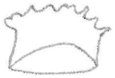

4.E.II.a.

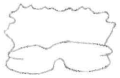

4.E.II.b.


4.E.III.


4.F.

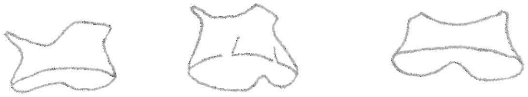

4.G.


4.H.


4.I.


5.A.I.

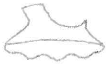

5.A.II.a.i.a.i.

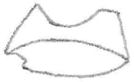

5.A.II.a.i.a.ii.

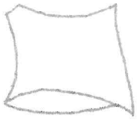

5.A.II.a.i.b.


5.A.II.a.ii.


5.A.II.a.iii.


5.A.II.a.iv.


5.A.II.b.


5.A.II.c.


5.A.III.

5. Projections on top (composite of flat and spiked projections)

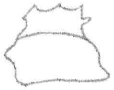
- **B. Three projections**
  - **I. “Type 1” (two spikes on one side with one flat projection on the other)**
    - a. Entire base, irregular sides (one concave and one straight), short
    - b. Indented base
      - i. One indentation on the side of the base, short
      - ii. Two indentations
        - a. One indentation on either side of the base
          - i. Tall, concave and irregular sides
          - ii. Short, irregular sides
        - b. Irregular indentations
          - i. Tall, both indentations on the side of the base, concave sides
          - ii. Short, both indentations near the centre of the base, concave sides
      - iii. Three indentations, concave sides, one indentation in the centre and one on either side or all three near the centre of the base
        - a. Tall
        - b. Short
      - iv. Multiple indentations, short, concave sides
    - c. Concave base, concave sides, short
  - **II. “Type 2” (two spikes on either side with one flat projection in the centre)**
    - a. Tall, irregular with one spike on the side, concave sides, one indentation in the centre of the base
    - b. Short, concave sides, one indentation near the centre of the base
  - **III. “Type 3” (two flat projections on either side with one triangular spike in the centre)**
    - a. Entire base, concave sides, short
    - b. Indented base, one indentation in the centre of the base, concave sides, short
    - c. Concave base, short, concave sides
  - **IV. “Type 4” (two flat projections, one on the side of the top and one in the centre with one spike on the other side);** tall, one indentation in the centre of the base, wave on the side of the rondel, concave sides.

5.B.I.a.

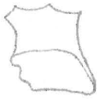
5.B.I.b.i.

5.B.I.b.ii.a.i.

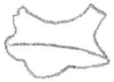
5.B.I.b.ii.a.ii.



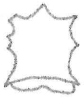
5.B.I.b.ii.b.i.



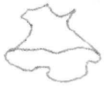
5.B.I.b.ii.b.ii.



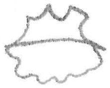
5.B.I.b.iii.a.



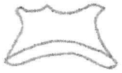
5.B.I.b.iii.b.



5.B.I.b.iv.

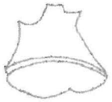


5.B.I.c.



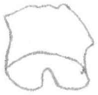
5.B.II.a.

5.B.II.b.



5.B.III.a.

5.B.III.b.



5.B.III.c.

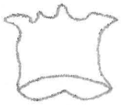
5.B.IV.

5. Projections on top (composite of flat and spiked projections)

- **C. Four projections**
  - I. Concave sides
    - a. One indentation in the centre of the base, short
    - b. Two indentations in the centre of the base, short
  - II. Irregular sides
    - a. One indentation in the centre of the base, tall
    - b. Two indentations, one on either side of the base, short
- **D. Five projections**
  - I. Concave sides
    - a. Two indentations, short, the indentations are near the centre of the base
    - b. Three inentations
      - i. Tall, irregular placed indentations in the base
      - ii. Short, one indentation in the centre of the base and one on either side
  - II. Straight sides, short, two indentations on the side of the base
  - III. Irregular sides, tall, two indentations near the centre of the base
- **E. Six projections;** concave sides, short

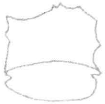
6. Projections on top (composite of waves, flat and spiked projection)

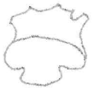
- **A. Three projections (one spike, one wave and one flat projection)**; concave sides, two indentations near the sides of the base, rondel is short
- **B. Four projections (one spike, two waves and one flat projection)**; concave sides, three irregular indentations, rondel is short
- **C. Five projections (irregular tops)**
  - I. Entire base, irregular sides, short
  - II. Concave base, short, concave and irregular sides (straight and concave)


5.C.I.a.


5.C.I.b.

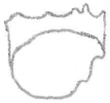

5.C.II.a.


5.C.II.b.


5.D.I.a.


5.D.I.b.i.

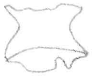

5.D.I.b.ii.


5.D.II.

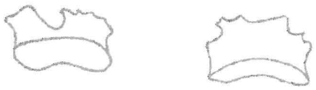

5.D.III.


5.E.


6.A.


6.B.


6.C.I.


6.C.II.

Rondel "Confusers"

Trichomes

1. No projections on the side

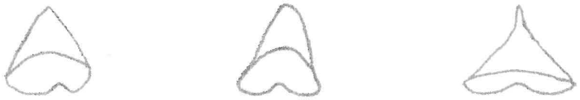
- A. Entire base
  - I. Tall
  - II. Short
- B. Indented base
  - I. One indentation, the indentation is in the middle of the base, short
  - II. Three indentations, irregular placed indentations in the base, short

2. Projections on the side

- A. Entire base, irregular sides, short and tall
- B. Indented base, irregular sides, short and tall

1.A.I.

1.A.II.



1.B.I.

1.B.II.

2.A.

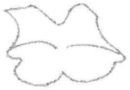
2.B.

Crosses

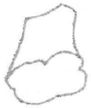
1. One projection on top (wavy, non-spiked)
  A. Type 1 (one crest and one trough), concave sides, short
  B. Type 2 (one crest, one trough and one crest), concave sides, short
2. One projection on top spiked (symmetrical or nearly so)
  A. One spiked, spike is triangular, concave sides, tall
  B. Two spiked, spikes are sharp, concave sides, short
  C. Three spiked, spikes are sharp, concave sides, short
  D. Four spiked
    I. No projections on the side, concave sides, short
    II. Projections on the side, irregular sides, tall
  E. Seven spiked, concave sides, spikes are sharp, short
3. Irregular spiked (irregular sides, short)

1.A.

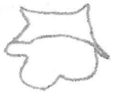
1.B.

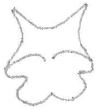


2.A.

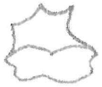


2.B.

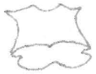




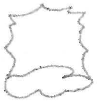
2.C



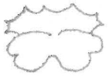
2.D.I.



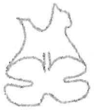
2.D.II.

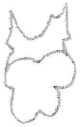


2.E.



3.





Rondels

1.A.I.a.i.	(Very common, found in: *Agrostis scabra, Alopecurus aequalis, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Danthonia spicata, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Glyceria grandis, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Leersia oryzoides, Millium effusum, Oryzopsis asperfolia, Oryzopsis pungens, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Poa palustris, Schedonorus pratensis, Schizachne purpurascens, Sphenopholis intermedia, Torreyochola pallida, Zea mays,* and *Zizania palustris*)
1.A.I.a.ii.	(Very common, found in: *Agrostis scabra, Alopecurus aequalis, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Cinna latifolia, Danthonia spicata, Deschampsia cespitosa, Dichanthelium acuminatum, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Glyceria grandis, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Millium effusum, Muhlenbergia glomerata, Oryzopsis asperfolia, Oryzopsis canadensis, Oryzopsis pungens, Panicum capillare, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Poa palustris, Schedonorus pratensis, Schizachne purpurascens, Sphenopholis intermedia, Sporobolus neglectus, Torreyochola pallida, Trisetum spicatum, Zea mays, Zizania aquatica,* and *Zizania palustris*)
1.A.I.b.i.	(Common, found in: *Danthonia spicata, Distichlis spicata, Eragrosis hypnoides, Oryzopsis asperfolia, Pascopyrum smithii, Phragmites australis, Schedonorus pratensis,* and *Zea mays*)
1.A.I.b.ii.	(Very common, found in: *Agrostis scabra, Alopecurus aequalis, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Cinna latifolia, Danthonia spicata, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Glyceria grandis, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Millium effusum, Oryzopsis asperfolia, Oryzopsis canadensis, Oryzopsis pungens, Panicum capillare, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Poa palustris, Schedonorus pratensis, Schizachne purpurascens, Sphenopholis intermedia, Sporobolus neglectus, Torreyochola pallida, Trisetum spicatum, Zea mays,* and *Zizania palustris*)
1.A.II.a.i.a.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Beckmannia syzigachne, Dichanthelium acuminatum, Elymus canadensis, Festuca rubra, Glyceria grandis, Hesperostipa comata, Hordeum jubatum, Leersia oryzoides, Millium effusum, Oryzopsis asperfolia, Oryzopsis pungens, Panicum capillare, Phragmites australis, Schizachne purpurascens, Torreyochola pallida, Zea mays, Zizania aquatica,* and *Zizania palustris)*
1.A.II.a.i.b.i.	(Common, found in: *Andropogon gerardii, Danthonia spicata, Dichanthelium acuminatum, Glyceria grandis, Oryzopsis pungens, Zizania aquatica,* and *Zizania palustris)*
1.A.II.a.i.b.ii.	(Very common, found in: *Beckmannia syzigachne, Danthonia spicata, Eragrosis hypnoides, Glyceria grandis, Hesperostipa comata, Hordeum jubatum, Leersia oryzoides, Oryzopsis canadensis, Oryzopsis pungens, Panicum capillare, Phalaris arundinacea, Schizachne purpurascens,* and *Torreyochola pallida*)

1.A.II.a.ii.a.	(Very common, found in: *Andropogon gerardii, Beckmannia syzigachne, Danthonia spicata, Glyceria grandis, Panicum capillare, Zea mays,* and *Zizania palustris*)
1.A.II.a.ii.b.	(Very common, found in: *Festuca rubra, Glyceria grandis, Graphephorum melicoides, Phalaris arundinacea, Poa palustris,* and *Schizachne purpurascens*)
1.A.II.b.i.a.	(Very rare, found in: *Zizania aquatica*)
1.A.II.b.i.b.	(Very rare, found in: *Oryzopsis pungens*)
1.A.II.b.ii.a.	(Very common, found in: *Danthonia spicata, Festuca rubra, Glyceria grandis, Oryzopsis pungens, Panicum capillare, Phalaris arundinacea, Schizachne purpurascens,* and *Zizania palustris*)
1.A.II.b.ii.b.	(Very rare, found in: *Danthonia spicata* and *Phalaris arundinacea*)
1.A.II.c.i.	(Very rare, found in: *Agrostis scabra*)
1.A.II.c.ii.	(Rare, found in: *Festuca rubra*, *Oryzopsis pungens*, and *Poa palustris*)
1.A.III.	(Very common, found in: *Andropogon gerardii, Deschampsia cespitosa, Distichlis spicata, Hesperostipa comata, Koeleria macrantha, Oryzopsis pungens, Phragmites australis, Poa palustris,* and *Zea mays*)
1.B.I.a.i.	(Rare, found in: *Deschampsia cespitosa, Leersia oryzoides*, and *Zizania palustris*)
1.B.I.a.ii.	(Common, found in: *Andropogon gerardii, Danthonia spicata, Deschampsia cespitosa,* and *Dichanthelium acuminatum*)
1.B.I.b.i.	(Very rare, found in: *Agrostis scabra*)
1.B.I.b.ii.a.	(Very rare, found in: *Zizania palustris*)
1.B.I.b.ii.b.	(Very rare, found in: *Deschampsia cespitosa*)
1.B.I.b.iii.	(Very rare, found in: *Beckmannia syzigachne*)
1.B.II.	(Very rare, found in: *Hesperostipa comata* and *Hordeum jubatum*)
1.C.I.	(Very common, found in: *Bromus ciliatus, Distichlis spicata, Elymus canadensis, Hordeum jubatum, Koeleria macrantha*, and *Pascopyrum smithii*)

1.C.II.	(Very common, found in: *Andropogon gerardii, Beckmannia syzigachne, Danthonia spicata, Deschampsia cespitosa, Dichanthelium acuminatum, Distichlis spicata, Eragrostis hypnoides, Glyceria grandis, Hesperostipa comata, Leersia oryzoides, Oryzopsis asperfolia, Oryzopsis pungens, Phragmites australis, Schizachne purpurascens, Zea mays* and *Zizania palustris*)
2.A.I.a.	(Common, found in: *Eragrosis hypnoides, Hordeum jubatum, Leersia oryzoides, Oryzopsis asperfolia, Phalaris arundinacea,* and *Schedonorus pratensis*)
2.A.I.b.i.	(Common, found in: *Danthonia spicata,Eragrosis hypnoides, Leersia oryzoides, Pascopyrum smithii, Poa palustris,* and *Schedonorus pratensis*)
2.A.I.b.ii.a.i.	(Very rare, found in: *Zizania palustris*)
2.A.I.b.ii.a.ii.	(Very rare, found in: *Zea mays*)
2.A.I.b.ii.b.	(Very rare, found in: *Andropogon gerardii*)
2.A.I.b.iii.	(Very common, found in: *Hesperostipa comata, Oryzopsis asperfolia*, and *Zea mays*)
2.A.I.c.	(Very rare, found in: *Zea mays*)
2.A.II.a.i.	(Common, found in: *Hesperostipa comata, Leersia oryzoides, Oryzopsis asperfolia, Zea mays* and *Zizania palustris*)
2.A.II.a.ii.	(Found in: *Guadua angustifolia*)
2.A.II.b.i.a.	(Very rare, found in: *Oryzopsis asperfolia*)
2.A.II.b.i.b.	(Very common, found in: *Oryzopsis asperfolia* and *Zizania aquatica*)
2.A.II.b.ii.	(Very rare, found in: *Leersia oryzoides*)
2.B.I.	(Rare, found in: *Panicum capillare, Schizachne purpurascens*, and *Zizania palustris*)
2.B.II.	(Very rare, found in: *Danthonia spicata*)
2.C.I.a.	(Very common, found in *Zea mays*)
2.C.I.b.i.a.i.	(Common, found in: *Andropogon gerardii, Zizania aquatica,* and *Zizania palustris*)
2.C.I.b.i.a.ii.	(Very common, found in: *Dichanthelium acuminatum, Distichlis spicata, Festuca rubra, Koeleria macrantha, Leersia oryzoides, Muhlenbergia glomerata, Phragmites australis, Sporobolus neglectus,* and *Zizania aquatica*)

2.C.I.b.i.b.	(Common, found in: *Danthonia spicata, Distichlis spicata, Leersia oryzoides, Sphenopholis intermedia,* and *Sporobolus neglectus*)
2.C.I.b.i.c.	(Very rare, found in: *Andropogon gerardii, Hordeum jubatum,* and *Leersia oryzoides*)
2.C.I.b.ii.a.	(Very rare, found in: *Hordeum jubatum* and *Schizachne purpurascens*)
2.C.I.b.ii.b.	(Very rare, found in: *Oryzopsis canadensis*)
2.C.I.c.i.	(Common, found in: *Eragrostis hypnoides, Hesperostipa comata, Oryzopsis asperfolia,* and *Oryzopsis pungens*)
2.C.I.c.ii.	(Very rare, found in: *Schedonorus pratensis*)
2.C.II.	(Very rare, found in: *Zea mays*)
2.C.III.a.	(Very common, found in: *Bromus ciliatus, Distichlis spicata, Elymus canadensis, Hordeum jubatum,* and *Koeleria macrantha*)
2.C.III.b.	(Very rare, found in: *Danthonia spicata*)
2.C.III.c.	(Very rare, found in: *Hesperostipa comata*)
2.C.IV.a.i.	(Very rare, found in: *Phragmites australis*)
2.C.IV.a.ii.	(Very rare, found in: *Poa palustris*)
2.C.IV.b.i.	(Common, found in: *Andropogon gerardii, Eragrostis hypnoides, Leersia oryzoides, Panicum capillare, Phalaris arundinacea, Phragmites australis, Schizachne purpurascens,* and *Zizania palustris*)
2.C.IV.b.ii.	(Very rare, found in: *Hordeum jubatum* and *Phalaris arundinacea*)
2.C.V.a.i.	(Very rare, found in: *Zea mays* and *Zizania palustris*)
2.C.V.a.ii.	(Very rare, found in: *Phalaris arundinacea*)
2.C.V.b.	(Very rare, found in: *Hordeum jubatum*)
2.C.VI.a.	(Very rare, found in: *Zea mays*)
2.C.VI.b.i.	(Very rare, found in: *Oryzopsis pungens*)
2.C.VI.b.ii.	(Very rare, found in: *Panicum capillare*)

2.C.VII.a.i.	(Very rare, found in: *Koeleria macrantha* and *Sphenopholis intermedia*)
2.C.VII.a.ii.	(Very rare, found in: *Zizania palustris*)
2.C.VII.b.	(Very rare, found in: *Zizania palustris*)
2.C.VII.c.	(Very rare, found in: *Hesperostipa comata*)
2.C.VIII.a.	(Common, found in: *Calamagrostis canadensis, Elymus canadensis, Festuca rubra, Oryzopsis asperfolia,* and Zea mays)
2.C.VIII.b.	(Very rare, found in: *Pascopyrum smithii* and *Schedonorus pratensis*)
2.D.	(Very rare, found in: *Dichanthelium acuminatum*)
3.A.I.a.	(Very common, found in: *Beckmannia syzigachne, Bromus ciliatus, Dichanthelium acuminatum, Elymus Canadensis, Glyceria grandis, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Zea mays* and *Zizania palustris*)
3.A.I.b.i.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Beckmannia syzigachne, Danthonia spicata, Deschampsia cespitosa, Festuca rubra, Koeleria macrantha, Phragmites australis, Poa palustris, Schedonorus pratensis, Schizachne purpurascens, Sphenopholis intermedia, Sporobolus neglectus,* and *Torreyochloa pallida*)
3.A.I.b.ii.a.i.	(Very rare, found in: *Zea mays* and *Zizania palustris*)
3.A.I.b.ii.a.ii.	(Very common, found in: *Andropogon gerardii, Beckmannia syzigachne, Danthonia spicata, Elymus Canadensis, Glyceria grandis, Hordeum jubatum, Oryzopsis asperfolia, Oryzopsis pungens, Panicum capillare, Phalaris arundinacea,* and *Phragmites australis*)
3.A.I.b.ii.b.	(Common, found in: *Andropogon gerardii, Distichlis spicata, Glyceria grandis, Hordeum jubatum, Leersia oryzoides, Phalaris arundinacea, Poa palustris,* and *Zizania palustris*)
3.A.I.b.ii.c.	(Very rare, found in: *Andropogon gerardii* and *Leersia oryzoides*)
3.A.I.c.	(Very common, found in: *Agrostis scabra, Calamagrostis canadensis, Cinna latifolia, Distichlis spicata, Festuca rubra, Hordeum jubatum,* and *Phalaris arundinacea*)
3.A.II.a.	(Very rare, found in: *Eragrostis hypnoides, Zea mays* and *Zizania palustris*)
3.A.II.b.i.	(Very rare, found in: *Hordeum jubatum*)
3.A.II.b.ii.	(Very rare, found in: *Zizania palustris*)

3.A.III.a.i.	(Rare, found in: *Oryzopsis asperfolia*)
3.A.III.a.ii.	(Very rare, found in: *Hesperostipa comata* and *Zea mays*)
3.A.III.b.i.	(Very rare, found in: *Agrostis scabra, Zizania aquatica* and *Zizania palustris*)
3.A.III.b.ii.	(Rare, found in: *Danthonia spicata* and *Hordeum jubatum*)
3.A.IV.a.	(Common, found in: *Andropogon gerardii, Muhlenbergia glomerata,* and *Oryzopsis asperfolia*)
3.A.IV.b.	(Very rare, found in: *Andropogon gerardii* and *Zizania palustris*)
3.A.V.a.	(Very rare, found in: *Zea mays* and *Zizania palustris*)
3.A.V.b.	(Very rare, found in: *Panicum capillare*)
3.A.VI.a.	(Rare, found in: *Festuca rubra, Hordeum jubatum, Leersia oryzoides, Pascopyrum smithii,* and *Zea mays*)
3.A.VI.b.i.	(Rare, found in: *Andropogon gerardii, Zea mays* and *Zizania palustris*)
3.A.VI.b.ii.a.	(Rare, found in: *Agrostis scabra, Andropogon gerardii, Leersia oryzoides,* and *Zizania palustris*)
3.A.VI.b.ii.b.	(Very rare, found in: *Zizania palustris*)
3.A.VI.b.iii.	(Very rare, found in: *Zizania palustris*)
3.B.I.a.	(Very common, found in: *Bromus ciliatus, Calamagrostis canadensis, Eragrostis hypnoides, Festuca rubra, Hesperostipa comata, Leersia oryzoides, Panicum capillare, Schedonorus pratensis,* and *Zizania palustris*)
3.B.I.b.i.	(Common, found in: *Calamagrostis Canadensis, Festuca rubra, Panicum capillare,* and *Zizania palustris*)
3.B.I.b.ii.	(Common, found in: *Calamagrostis canadensis, Leersia oryzoides, Panicum capillare, Schedonorus pratensis,* and *Schizachne purpurascens*)
3.B.I.b.iii.	(Very rare, found in: *Danthonia spicata* and *Panicum capillare*)
3.B.II.a.	(Very rare, found in: *Distichlis spicata*)
3.B.II.b.i.	(Very rare, found in: *Muhlenbergia glomerata* and *Zizania aquatica*)

3.B.II.b.ii.a.	(Very rare, found in: *Festuca rubra* and *Schizachne purpurascens*)
3.B.II.b.ii.b.	(Very common, found in: Beckmannia syzigachne, Cinna latifolia, Festuca rubra, and Hesperostipa comata)
3.B.II.c.	(Very rare, found in: *Oryzopsis asperfolia*)
3.B.III.a.i.	(Very rare, found in: *Oryzopsis asperfolia* and *Zizania palustris*)
3.B.III.a.ii.	(Very common, found in: *Hesperostipa comata, Leersia oryzoides, Oryzopsis asperfolia, Phragmites australis, Poa palustris,* and *Zizania palustris*)
3.B.III.b.i.	(Common, found in: *Festuca rubra, Oryzopsis asperfolia, Zea mays,* and *Zizania palustris*)
3.B.III.b.ii.	(Very rare, found in: *Calamagrostis canadensis* and *Zea mays*)
3.B.III.c.	(Very rare, found in: *Hesperostipa comata* and *Oryzopsis asperfolia*)
3.B.IV.a.i.a.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis canadensis, Cinna latifolia, Danthonia spicata, Deschampsia cespitosa, Dichanthelium acuminatum, Elymus canadensis, Eragrostis hypnoides, Festuca rubra, Hesperostipa comata, Leersia oryzoides, Oryzopsis asperfolia, Oryzopsis pungens, Phragmites australis, Schedonorus pratensis, Schizachne purpurascens, Zea mays, Zizania aquatica* and *Zizania palustris*)
3.B.IV.a.i.b.	(Very common, found in: *Calamagrostis canadensis, Danthonia spicata, Elymus canadensis, Eragrostis hypnoides, Festuca rubra, Hesperostipa comata, Hordeum jubatum, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Poa palustris,* and *Zea mays*)
3.B.IV.a.ii.	(Very rare, found in: *Beckmannia syzigachne* and *Festuca rubra*)
3.B.IV.a.iii.	(Very rare, found in: *Bromus ciliatus, Oryzopsis pungens,* and *Zizania palustris*)
3.B.IV.b.i.a.i.a.	(Very common, found in: *Andropogon gerardii, Beckmannia syzygachne, Danthonia spicata, Festuca rubra, Hesperostipa comata, Oryzopsis pungens, Panicum capillare, Phalaris arundinacea, Phragmites australis, Schizachne purpurascens,* and *Zizania palustris*)
3.B.IV.b.i.a.i.b.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Eragrostis hypnoides, Muhlenbergia glomerata, Panicum capillare, Phalaris arundinacea, Sporobolus neglectus, Zea mays,* and *Zizania palustris*)
3.B.IV.b.i.a.ii.	(Very rare, found in: *Oryzopsis pungens*)
3.B.IV.b.i.b.i.	(Very rare, found in: *Danthonia spicata* and *Zea mays*)
3.B.IV.b.i.b.ii.a.	(Very rare, found in: *Zizania palustris*)

3.B.IV.b.i.b.ii.b.	(Very common, found in: *Danthonia spicata, Dichanthelium acuminatum, Panicum capillare,* and *Zizania palustris*)
3.B.IV.b.i.b.iii.	(Very rare, found in: *Andropogon gerardii, Danthonia spicata,* and *Zizania palustris*)
3.B.IV.b.i.c.i.a.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Glyceria grandis, Panicum capillare,* and *Zizania palustris*)
3.B.IV.b.i.c.i.b.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Panicum capillare, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.B.IV.b.i.c.ii.	(Very common, found in: *Andropogon gerardii, Panicum capillare, Poa palustris,* and *Zizania palustris*)
3.B.IV.b.ii.a.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Beckmannia syzigachne, Cinna latifolia, Danthonia spicata, Dichanthelium acuminatum, Distichlis spicata, Eragrostis hypnoides, Glyceria grandis, Hesperostipa comata, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Oryzopsis canadensis, Oryzopsis pungens, Panicum capillare, Phragmites australis, Poa palustris, Schedonorus pratensis, Schizachne purpurascens, Sporobolus neglectus, Torreyochloa pallida, Zea mays, Zizania aquatica* and *Zizania palustris*)
3.B.IV.b.ii.b.i.	(Common, found in: *Danthonia spicata, Leersia oryzoides,* and *Zizania aquatica*)
3.B.IV.b.ii.b.ii.	(Rare, found in: *Glyceria grandis* and *Leersia oryzoides*)
3.B.IV.c.i.a.	(Very rare, found in: *Danthonia spicata, Schizachne purpurascens,* and *Zizania palustris*)
3.B.IV.c.i.b.	(Very common, found in: *Calamagrostis canadensis, Hesperostipa comata, Muhlenbergia glomerata, Oryzopsis pungens, Phragmites australis, Sporobolus neglectus,* and *Zea mays*)
3.B.IV.c.ii.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Beckmannia syzigachne, Calamagrostis canadensis, Cinna latifolia, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Festuca rubra, Hesperostipa comata, Hordeum jubatum, Leersia oryzoides, Millium effusum, Oryzopsis asperfolia, Panicum capillare, Phalaris arundinacea, Phragmites australis, Schedonorus pratensis, Schizachne purpurascens, Sporobolus neglectus,* and *Zea mays*)
3.B.IV.c.iii.	(Very rare, found in: *Eragrostis hypnoides, Festuca rubra,* and *Hesperostipa comata*)
3.B.V.a.	(Very rare, found in: *Elymus canadensis* and *Hordeum jubatum*)
3.B.V.b.i.	(Very rare, found in: *Hesperostipa comata* and *Zizania aquatica*)
3.B.V.b.ii.a.	(Very rare, found in: *Cinna latifolia* and *Danthonia spicata*)
3.B.V.b.ii.b.	(Very rare, found in: *Hordeum jubatum*)
3.B.VI.a.i.	(Rare, found in: *Hordeum jubatum* and *Oryzopsis asperfolia*)

3.B.VI.a.ii.	(Very common, found in: *Alopecurus aequalis, Bromus ciliatus, Calamagrostis canadensis, Cinna latifolia, Deschampsia cespitosa, Festuca rubra, Koeleria macrantha, Pascopyrum smithii,* and *Schedonorus pratensis*)
3.B.VI.a.iii.a.	(Very rare, found in: *Leersia oryzoides*)
3.B.VI.a.iii.b.	(Very rare, found in: *Bromus ciliatus* and *Elymus canadensis*)
3.B.VI.b.i.	(Common, found in: *Andropogon gerardii, Danthonia spicata,* and *Deschampsia cespitosa*)
3.B.VI.b.ii.	(Very rare, found in: *Andropogon gerardii* and *Leersia oryzoides*)
3.B.VI.c.i.	(Rare, found in: *Hesperostipa comata, Oryzopsis asperfolia,* and *Oryzopsis pungens*)
3.B.VI.c.ii.	(Very rare, found in: *Hesperostipa comata*)
3.C.I.a.i.a.	(Very common, found in: *Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Leersia oryzoides, Oryzopsis asperfolia, Panicum capillare, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Poa palustris, Schizachne purpurascens, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.C.I.a.i.b.	(very common, found in: *Agrostis scabra, Alopecurus aequalis, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Cinna latifolia, Danthonia spicata, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Oryzopsis pungens, Panicum capillare, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Schedonorus pratensis, Schizachne purpurascens, Sporobolus neglectus, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.C.I.a.ii.a.	(Very rare, found in: *Oryzopsis pungens*)
3.C.I.a.ii.b.	(Very common, found in: *Bromus ciliatus, Deschamspia cespitosa,* and *Panicum capillare*)
3.C.I.b.i.a.i.a.	(Very common, found in: *Danthonia spicata, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Schizachne purpurascens, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.C.I.b.i.a.i.b.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Dichanthelium acuminatum, Hesperostipa comata, Oryzopsis pungens, Panicum capillare, Zea mays* and *Zizania palustris*)
3.C.I.b.i.a.ii.a.	(Rare, found in: *Hesperostipa comata*)
3.C.I.b.i.a.ii.b.	(Very rare, found in: *Danthonia spicata* and *Deschampsia cespitosa*)

3.C.I.b.i.b.i.a.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.C.I.b.i.b.i.b.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Hordeum jubatum, Panicum capillare, Phalaris arundinacea, Schizachne purpurascens,* and *Zizania palustris*)
3.C.I.b.i.b.ii.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Dichanthelium acuminatum, Hesperostipa comata, Leersia oryzoides, Phalaris arundinacea, Schizachne purpurascens, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.C.I.b.i.c.i.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.C.I.b.i.c.ii.	(Very common, found in: *Andropogon gerardii, Dichanthelium acuminatum, Zizania aquatica,* and *Zizania palustris*)
3.C.I.b.i.d.	(Very rare, found in: *Festuca rubra*)
3.C.I.b.ii.	(Very common, found in: *Agrostis scabra, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis canadensis, Deschampsia cespitosa, Festuca rubra, Graphephorum melicoides, Hordeum jubatum, Millium effusum, Oryzopsis pungens, Phragmites australis, Schedonorus pratensis,* and *Schizachne purpurascens*)
3.C.I.c.i.	(Very common, found in: *Andropogon gerardii, Hesperostipa comata, Oryzopsis pungens,* and *Phragmites australis*)
3.C.I.c.ii.	(Common, found in: *Beckmannia syzigachne, Cinna latifolia, Danthonia spicata, Deschampsia cespitosa, Oryzopsis pungens, Pascopyrum smithii, Phalaris arundinacea,* and *Schedonorus pratensis*)
3.C.I.d.i.	(Very rare, found in: *Oryzopsis asperfolia*)
3.C.I.d.ii.	(Very rare, found in: *Zizania palustris*)
3.C.II.a.	(Very common, found in: *Alopecurus aequalis, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Schedonorus pratensis, Sphenopholis intermedia, Zea mays,* and *Zizania palustris*)
3.C.II.b.i.a.	(Very rare, found in: *Zizania aquatica* and *Zizania palustris*)
3.C.II.b.i.b.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Dichanthelium acuminatum, Muhlenbergia glomerata, Oryzopsis asperfolia, Panicum capillare, Schizachne purpurascens, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.C.II.b.ii.a.	(Rare, found in: *Andropogon gerardii, Festuca rubra, Phalaris arundinacea* and *Zizania palustris*)

3.C.II.b.ii.b.	(Common, found in: *Schizachne purpurascens* and *Zizania palustris*)
3.C.II.c.i.	(Very rare, found in: *Hesperostipa comata* and *Phragmites australis*)
3.C.II.c.ii.	(Rare, found in: *Festuca rubra, Oryzopsis pungens* and *Schedonorus pratensis*)
3.C.III.a.i.	(Rare, found in: *Oryzopsis asperfolia, Schedonorus pratensis,* and *Zizania palustris*)
3.C.III.a.ii.	(Very rare, found in: *Festuca rubra* and *Schedonorus pratensis*)
3.C.III.b.i.a.	(Very common, found in: *Bromus ciliatus, Danthonia spicata, Festuca rubra, Schedonorus pratensis,* and *Zizania palustris*)
3.C.III.b.i.b.	(Rare, found in: Andropogon gerardii, Festuca rubra, and Zizania palustris)
3.C.III.b.ii.	(Very rare, found in: *Danthonia spicata*)
3.C.III.b.iii.	(Very rare, found in: *Zizania palustris*)
3.C.III.c.	(Very rare, found in: *Leersia oryzoides* and *Schedonorus pratensis*)
3.D.I.a.i.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Danthonia spicata, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Oryzopsis pungens, Panicum capillare, Pascopyrum smithii, Phragmites australis, Schedonorus pratensis, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.D.I.a.ii.	(Very common, found in: *Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Danthonia spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Oryzopsis asperfolia, Panicum capillare, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Schedonorus pratensis, Zea mays, Zizania aquatica,* and *Zizania palustris*)
3.D.I.b.i.a.i.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.D.I.b.i.a.ii.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.D.I.b.i.b.i.	(Common, found in: *Andropogon gerardii, Beckmannia syzigachne, Festuca rubra, Hordeum jubatum, Leersia oryzoides, Oryzopsis asperfolia,* and *Schizachne purpurascens)*
3.D.I.b.i.b.ii.	(Rare, found in: *Beckmannia syzigachne, Hesperostipa comata, Oryzopsis pungens, Panicum capillare,* and *Phalaris arundinacea*)
3.D.I.b.ii.a.i.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)

3.D.I.b.ii.a.ii.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Hordeum jubatum, Zizania aquatica* and *Zizania palustris*)
3.D.I.b.ii.b.	(Very rare, found in: *Zizania palustris*)
3.D.I.b.iii.a.i.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.D.I.b.iii.a.ii.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.D.I.b.iii.b.i.	(Very rare, found in: *Zizania palustris*)
3.D.I.b.iii.b.ii.	(Very rare, found in: *Andropogon gerardii*)
3.D.I.b.iii.c.	(Very rare, found in: *Zizania palustris*)
3.D.I.c.i.	(Very common, found in: *Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Festuca rubra, Hesperostipa comata, Pascopyrum smithii, Phragmites australis,* and *Schedonorus pratensis*)
3.D.I.c.ii.	(Very rare, found in: *Distichlis spicata, Festuca rubra,* and *Oryzopsis pungens*)
3.D.I.d.	(Very rare, found in: *Danthonia spicata* and *Hesperostipa comata*)
3.D.II.a.	(Common, found in: *Bromus ciliatus, Danthonia spicata, Deschampsia cespitosa, Elymus canadensis, Hordeum jubatum, and Schedonorus pratensis*)
3.D.II.b.i.a.	(Very rare, found in: *Zizania palustris*)
3.D.II.b.i.b.	(Rare, found in: Danthonia spicata, Dichanthelium acuminatum, Oryzopsis asperfolia, and Panicum capillare)
3.D.II.b.ii.	(Common, found in: *Panicum capillare* and *Zizania palustris*)
3.D.II.c.	(Rare, found in: *Danthonia spicata, Dichanthelium acuminatum, Oryzopsis asperfolia, Panicum capillare,* and *Zizania palustris*)
3.D.III.a.i.	(Very rare, found in: *Koeleria macrantha*)
3.D.III.a.ii.	(Common, found in: Beckmannia syzigachne, Festuca rubra, Schedonorus pratensis, Schizachne purpurascens, and Zizania palustris)
3.D.III.b.i.a.	(Rare, found in: Hesperostipa comata, Hordeum jubatum, and Zizania palustris)

3.D.III.b.i.b.	(Very common, found in: *Deschampsia cespitosa, Elymus Canadensis, Oryzopsis pungens, Panicum capillare, Phragmites australis, Schedonorus pratensis,* and *Zizania palustris*)
3.D.III.b.ii.a.	(Rare, found in: *Zizania palustris*)
3.D.III.b.ii.b.	(Very rare, found in: *Zea mays* and *Zizania palustris*)
3.E.I.a.i.	(Common, found in: *Festuca rubra, Hordeum jubatum, Oryzopsis pungens, Schedonorus pratensis, Zea mays* and *Zizania palustris*)
3.E.I.a.ii.	(Common, found in: *Festuca rubra, Hordeum jubatum, Schedonorus pratensis, Zea mays* and *Zizania palustris*)
3.E.I.b.i.a.	(Rare, found in: *Zizania palustris*)
3.E.I.b.i.b.	(Rare, found in: *Deschampsia cespitosa* and *Zizania palustris*)
3.E.I.b.ii.a.	(Very rare, found in: *Zizania palustris*)
3.E.I.b.ii.b.	(Rare, found in: *Zizania palustris*)
3.E.I.b.iii.a.i.	(Rare, found in: *Zizania palustris*)
3.E.I.b.iii.a.ii.	(Very common, found in: *Zizania aquatica* and *Zizania palustris*)
3.E.I.b.iii.b.	(Very rare, found in: *Zizania palustris*)
3.E.II.a.i.	(Very common, found in: *Deschampsia cespitosa* and *Schedonorus pratensis*)
3.E.II.a.ii.	(Very rare, found in: *Festuca rubra* and *Hordeum jubatum*)
3.E.II.b.i.a.i.	(Very rare, found in: *Zizania palustris*)
3.E.II.b.i.a.ii.	(Very rare, found in: *Beckmannia syzigachne* and *Zizania palustris*)
3.E.II.b.i.b.	(Very rare, found in: *Danthonia spicata, Festuca rubra,* and *Hordeum jubatum*)
3.E.II.b.ii.	(Very rare, found in: *Bromus ciliatus* and *Schedonorus pratensis*)
3.E.II.c.	(Very rare, found in: *Festuca rubra*)
3.E.II.d.	(Very rare, found in: *Muhlenbergia glomerata*)

3.F.I.a.i.	(Very common, found in: *Beckmannia syzigachne, Bromus ciliatus, Deschampsia cespitosa, Distichlis spicata, Elymus canadensis, Festuca rubra, Hordeum jubatum, Oryzopsis asperfolia,* and *Zizania aquatica*)
3.F.I.a.ii.	(Very rare, found in: *Festuca rubra*)
3.F.I.b.i.a.i.	(Very rare, found in: *Zizania palustris*)
3.F.I.b.i.a.ii.	(Very rare, found in: *Schedonorus pratensis*)
3.F.I.b.i.b.	(Rare, found in: *Zizania aquatica* and *Zizania palustris*)
3.F.I.b.ii.a.	(Common, found in: *Festuca rubra* and *Schedonorus pratensis*)
3.F.I.b.ii.b.	(Common, found in: *Festuca rubra, Schedonorus pratensis,* and *Zea mays*)
3.F.I.b.ii.c.	(Rare, found in: *Danthonia spicata* and *Festuca rubra*)
3.F.I.b.ii.d.	(Very rare, found in: *Festuca rubra*)
3.F.I.c.	(Very rare, found in: *Distichlis spicata, Phragmites australis*, and *Schedonorus pratensis*)
3.F.II.a.	(Very common, found in: *Festuca rubra, Hordeum jubatum* and *Schedonorus pratensis*)
3.F.II.b.	(Very rare, found in: *Zizania palustris*)
3.F.II.c.	(Very rare, found in: *Pascopyrum smithii*)
3.G.I.a.i.	(Very rare, found in: *Elymus canadensis*)
3.G.I.a.ii.	(Common, found in: *Beckmannia syzigachne* and *Festuca rubra*)
3.G.I.b.	(Very rare, found in: *Zizania palustris*)
3.G.II.a.	(Common, found in: *Hordeum jubatum* and *Zizania palustris*)
3.G.II.b.	(Rare, found in: *Zizania aquatica* and *Zizania palustris*)
3.H.	(Common, found in: *Zizania palustris*)

3.I.	(Rare, found in: *Deschampsia cespitosa, Oryzopsis asperfolia,* and *Zizania aquatica*)
4.A.I.a.i.	(Very rare, found in: *Leersia oryzoides*)
4.A.I.a.ii.	(Very rare, found in: *Hesperostipa comata* and *Zizania palustris*)
4.A.I.b.i.a.	(Very rare, found in: *Danthonia spicata*)
4.A.I.b.i.b.	(Very rare, found in: *Muhlenbergia glomerata* and *Panicum capillare*)
4.A.I.b.ii.	(Very rare, found in: *Andropogon gerardii*)
4.A.II.a.	(Common, found in: *Beckmannia syzigachne, Elymus canadensis, Hesperostipa comata, Hordeum jubatum, Oryzopsis asperfolia,* and *Pascopyrum smithii*)
4.A.II.b.i.	(Common, found in: *Andropogon gerardii, Calamagrostis canadensis, Danthonia spicata, Deschampsia cespitosa,* and *Panicum capillare*)
4.A.II.b.ii.	(Very rare, found in: *Calamagrostis canadensis*)
4.A.II.c.	(Very rare, found in: *Oryzopsis asperfolia*)
4.B.I.a.i.	(Rare, found in: *Guadua angustifolia, Zea mays,* and *Zizania palustris*)
4.B.I.a.ii.	(Common, found in: Beckmannia syzigachne, Calamagrostis canadensis, Elymus canadensis, Festuca rubra, Hesperostipa comata, Muhlenbergia glomerata, Pascopyrum smithii, Zea mays and Zizania palustris)
4.B.I.b.i.a.	(Very common, found in: Agrostis scabra, Dichanthelium acuminatum, Zea mays, Zizania aquatica and Zizania palustris)
4.B.I.b.i.b.	(Very common, found in: *Andropogon gerardii, Beckmannia syzigachne, Calamagrostis Canadensis, Cinna latifolia, Danthonia spicata, Dichanthelium acuminatum, Distichlis spicata, Festuca rubra, Glyceria grandis, Hesperostipa comata, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis asperfolia, Panicum capillare, Phalaris arundinacea, Poa palustris, Schizachne purpurascens, Sporobolus neglectus,* and *Zizania aquatica*)
4.B.I.b.ii.	(Very rare, found in: *Zea mays*)
4.B.I.b.iii.	(Very rare, found in: *Andropogon gerardii*)
4.B.I.c.	(Very rare, found in: *Eragrostis hypnoides* and *Hesperostipa comata*)
4.B.II.a.i.	(Very rare, found in: *Agrostis scabra, Koeleria macrantha,* and *Sphenopholis intermedia*)

4.B.II.a.ii.	(Very rare, found in: *Zea mays*)
4.B.II.b.i.	(Very rare, found in: *Danthonia spicata*)
4.B.II.b.ii.	(Very rare, found in: *Eragrostis hypnoides* and *Oryzopsis pungens*)
4.B.II.c.	(Very rare, found in: *Eragrostis hypnoides*)
4.B.III.a.	(Very common, found in: *Festuca rubra, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Oryzopsis asperfolia,* and *Schedonorus pratensis*)
4.B.III.b.i.	(Very rare, found in: *Andropogon gerardii* and *Zizania palustris*)
4.B.III.b.ii.	(Rare, found in: *Danthonia spicata, Oryzopsis pungens,* and *Phalaris arundinacea*)
4.B.III.c.	(Very rare, found in: *Schedonorus pratensis*)
4.B.IV.a.	(Common, found in: *Pascopyrum smithii, Phragmites australis,* and *Zizania palustris*)
4.B.IV.b.	(Very rare, found in: *Hordeum jubatum*)
4.C.I.a.	(Rare, found in: *Eragrostis hypnoides, Muhlenbergia glomerata, Phragmites australis, Schedonorus pratensis,* and *Zea mays*)
4.C.I.b.i.	(Very rare, found in: *Panicum capillare*)
4.C.I.b.ii.	(Very rare, found in: *Zizania palustris*)
4.C.I.c.	(Very rare, found in: *Eragrostis hypnoides, Festuca rubra,* and *Phragmites australis*)
4.C.II.a.i.	(Rare, found in: *Panicum capillare* and *Zea mays*)
4.C.II.a.ii.	(Very rare, found in: *Panicum capillare*)
4.C.II.b.i.	(Very rare, found in: *Panicum capillare* and *Schedonorus pratensis*)
4.C.II.b.ii.	(Very rare, found in: *Zizania palustris*)
4.C.III.a.	(Very rare, found in: *Hordeum jubatum* and *Pascopyrum smithii*)

4.C.III.b.i.	(Very rare, found in: *Andropogon gerardii* and *Deschampsia cespitosa*)
4.C.III.b.ii.	(Very rare, found in: *Danthonia spicata*)
4.C.III.c.	(Rare, found in: *Cinna latifolia, Koeleria macrantha, Oryzopsis asperfolia, Oryzopsis pungens,* and *Phragmites australis*)
4.C.IV.a.	(Very rare, found in: *Festuca rubra*)
4.C.IV.b.	(Very rare, found in: *Festuca rubra*)
4.C.IV.c.	(Very rare, found in: *Hesperostipa comata*)
4.D.I.a.	(Common, found in: *Elymus canadensis, Eragrostis hypnoides, Festuca rubra, Hesperostipa comata, Hordeum jubatum,* and *Oryzopsis asperfolia*)
4.D.I.b.	(Very rare, found in: *Festuca rubra*)
4.D.II.a.	(Very rare, found in: *Zizania palustris*)
4.D.II.b.	(Rare, found in: *Andropogon gerardii, Festuca rubra, Hordeum jubatum* and *Zea mays*)
4.D.II.c.	(Very rare, found in: *Zizania palustris*)
4.D.III.a.	(Rare, found in: *Festuca rubra, Hesperostipa comata, Oryzopsis pungens* and *Zizania palustris*)
4.D.III.b.	(Rare, found in: *Festuca rubra, Hesperostipa comata,* and *Schedonorus pratensis*)
4.D.IV.	(Very rare, found in: *Danthonia spicata*)
4.E.I.	(Rare, found in: *Beckmannia syzigachne, Eragrostis hypnoides,* and *Hordeum jubatum*)
4.E.II.a.	(Very rare, found in: *Zizania palustris*)
4.E.II.b.	(Rare, found in: *Elymus canadensis*)
4.E.III.	(Very rare, found in: *Oryzopsis asperfolia*)
4.F.	(Very rare, found in: *Andropogon gerardii, Zea mays,* and *Zizania palustris*)
4.G.	(Very rare, found in: *Hordeum jubatum* and *Schedonorus pratensis*)

4.H.	(Very common, found in: *Distichlis spicata, Festuca rubra, Hordeum jubatum,* and *Schedonorus pratentis*)
4.I.	(Very rare, found in: *Zizania aquatica*)
5.A.I.	(Common, found in: *Beckmannia syzigachne, Danthonia spicata, Distichlis spicata, Elymus canadensis, Hesperostipa comata, Oryzopsis pungens,* and *Poa palustris*)
5.A.II.a.i.a.i.	(Very rare, found in: *Zizania aquatica*)
5.A.II.a.i.a.ii.	(Very common, found in: *Andropogon gerardii, Danthonia spicata, Deschampsia cespitosa, Dichanthelium acuminatum, Distichlis spicata, Muhlenbergia glomerata, Oryzopsis asperfolia, Phragmites australis, Schedonorus pratensis, Zea mays, Zizania aquatica,* and *Zizania palustris*)
5.A.II.a.i.b.	(Very rare, found in: *Hordeum jubatum, Oryzopsis pungens,* and *Zea mays*)
5.A.II.a.ii.	(Common, found in: *Andropogon gerardii, Beckmannia syzigachne, Dichanthelium acuminatum, Hordeum jubatum, Leersia oryzoides, Muhlenbergia glomerata, Oryzopsis canadensis,* and *Oryzopsis pungens*)
5.A.II.a.iii.	(Common, found in: *Danthonia spicata* and *Zizania palustris*)
5.A.II.a.iv.	(Very rare, found in: *Zizania palustris*)
5.A.II.b.	(Very rare, found in: *Phalaris arundinacea* and *Schizachne purpurascens*)
5.A.II.c.	(Very rare, found in: *Zizania palustris*)
5.A.III.	(Common, found in: *Hesperostipa comata*)
5.B.I.a.	(Rare, found in: *Elymus canadensis, Hordeum jubatum,* and *Leersia oryzoides*)
5.B.I.b.i.	(Common, found in: *Danthonia spicata, Festuca rubra, Hesperostipa comata, Phalaris arundinacea,* and *Schizachne purpurascens*)
5.B.I.b.ii.a.i.	(Rare, found in: *Zea mays* and *Zizania palustris*)
5.B.I.b.ii.a.ii.	(Very rare, found in: *Festuca rubra*)
5.B.I.b.ii.b.i.	(Very rare, found in: *Phalaris arundinacea*)
5.B.I.b.ii.b.ii.	(Very rare, found in: *Oryzopsis asperfolia*)
5.B.I.b.ii.b.iii.	(Rare, found in: *Hesperostipa comata* and *Zizania palustris*)

5.B.I.b.ii.b.iv.	(Very rare, found in: *Calamagrostis canadensis*)
5.B.I.c.	(Rare, found in: *Oryzopsis asperfolia, Oryzopsis pungens,* and *Phragmites australis*)
5.B.II.a.	(Very rare, found in: *Zizania palustris*)
5.B.II.b.	(Very rare, found in: *Andropogon gerardii, Danthonia spicata,* and *Zizania palustris*)
5.B.III.a.	(Common, found in: *Eragrostis hypnoides, Panicum capillare,* and *Schedonorus pratensis*)
5.B.III.b.	(Very rare, found in: *Zizania aquatica*)
5.B.III.c.	(Very rare, found in: *Hesperostipa comata*)
5.B.IV.	(Very rare, found in: *Zizania palustris*)
5.C.I.a.	(Very rare, found in: *Zizania palustris*)
5.C.I.b.	(Rare, found in: *Danthonia spicata, Sporobolus neglectus, Zizania aquatica* and *Zizania palustris*)
5.C.II.a.	(Very rare, found in: *Zizania palustris*)
5.C.II.b.	(Very rare, found in: *Zizania palustris*)
5.D.I.a.	(Very rare, found in: *Dichanthelium acuminatum* and *Zizania palustris*)
5.D.I.b.i.	(Rare, found in: *Zizania palustris*)
5.D.I.b.ii.	(Very rare, found in: *Zizania palustris*)
5D.II.	(Very rare, found in: *Schedonorus pratensis*)
5.D.III.	(Very rare, found in: *Zizania palustris*)
5.E.	(Very rare, found in: *Hordeum jubatum, Schedonorus pratensis,* and *Zea mays*)
6.A.	(Very rare, found in: *Dichanthelium acuminatum*)
6.B.	(Very rare, found in: *Zea mays*)

6.C.I.	(Very rare, found in: *Oryzopsis asperfolia* and *Schedonorus pratensis*)
6.C.II.	(Very rare, found in: *Schedonorus pratensis*)

Rondel "Confusers"

Trichomes

1.A.I.	(Very common, found in: *Agrostis scabra, Alopecurus aequalis, Andropogon gerardii, Beckmannia syzigachne, Bromus ciliatus, Calamagrostis Canadensis, Cinna latifolia, Danthonia spicata, Deschampsia cespitosa, Dichanthelium acuminatum, Distichlis spicata, Elymus canadensis, Eragrosis hypnoides, Festuca rubra, Glyceria grandis, Graphephorum melicoides, Hesperostipa comata, Hordeum jubatum, Koeleria macrantha, Leersia oryzoides, Millium effusum, Oryzopsis asperfolia, Oryzopsis pungens, Panicum capillare, Pascopyrum smithii, Phalaris arundinacea, Phragmites australis, Poa palustris, Schedonorus pratensis, Schizachne purpurascens, Sphenopholis intermedia, Sporobolus neglectus, Torreyochola pallida, Trisetum spicatum,* and *Zea mays*)
1.A.II.	(Rare, found in: *Beckmannia syzigachne, Calamagrostis Canadensis, Graphephorum melicoides,* and *Zea mays*)
1.B.I.	(Very common, found in: *Agrostis scabra, Andropogon gerardii, Calamagrostis canadensis, Danthonia spicata, Dichanthelium acuminatum, Eragrosis hypnoides, Graphephorum melicoides, Hordeum jubatum, Leersia oryzoides, Millium effusum, Oryzopsis canadensi, Oryzopsis pungens, Phalaris arundinacea, Poa palustris, Schizachne purpurascens,* and *Zizania palustris*)
1.B.II.	(Rare, found in: *Agrostis scabra*)
2.A.	(Very common, found in: *Andropogon gerardii, Bromus ciliatus, Deschampsia cespitosa, Elymus canadensis, Hordeum jubatum,* and *Schedonorus pratensis*)
2.B.	(Very common, found in: Andropogon gerardii, Danthonia spicata, Dichanthelium acuminatum, Festuca rubra, Hordeum jubatum, Leersia oryzoides, Schizachne purpurascens, and Zizania palustris)

Crosses

1.A.	(Rare, found in: *Andropogon gerardii*)
1.B.	(Rare, found in: *Andropogon gerardii* and *Zizania palustris*)
2.A.	(Very rare, found in: *Andropogon gerardii*)
2.B.	(Common, found in: *Agrostis scabra, Andropogon gerardii, Calamagrostis canadensis,* and *Glyceria grandis*)
2.C.	(Very rare, found in: *Andropogon gerardii*)
2.D.I.	(Rare, found in: *Andropogon gerardii, Danthonia spicata* and *Zizania palustris*)

2.D.II.	(Very rare, found in: *Zizania palustris*)
2.E.	(Very rare, found in: *Zizania palustris*)
3.	(Very rare, found in: *Panicum capillare* and *Zizania palustris*)

APPENDIX C. POTSHERDS OF SELECTED SITES IN THE STUDY AREA REPRESENTING THE FOUR MAJOR CERAMIC TYPES

Figure 41. Laurel sherds from the Ballinamore site (DkKp-9).

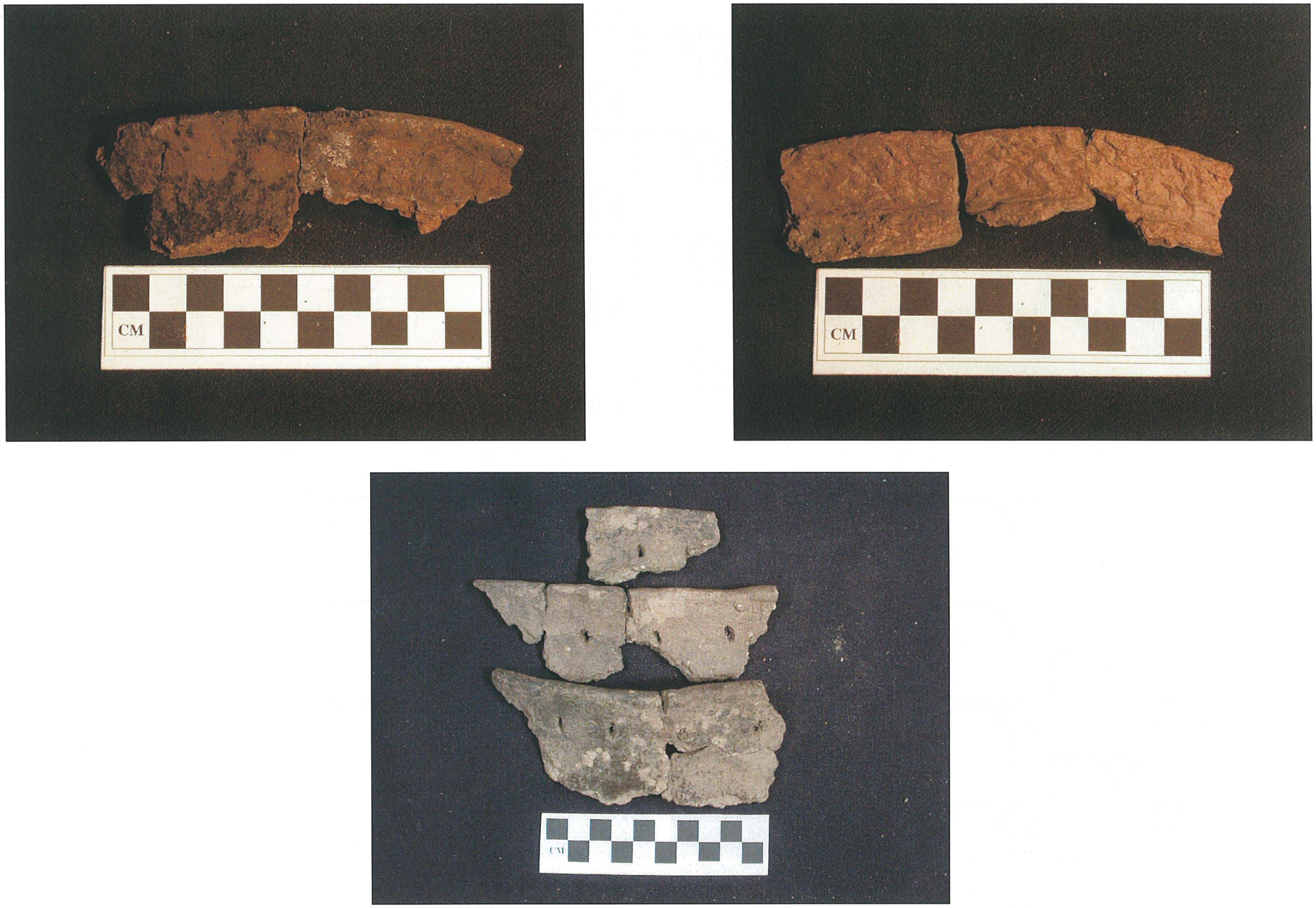


Figure 42. Selkirk sherds from the Ash Rapids East (DjKq-4), EcKf-8, and Bundoran (DjKn-5) sites.

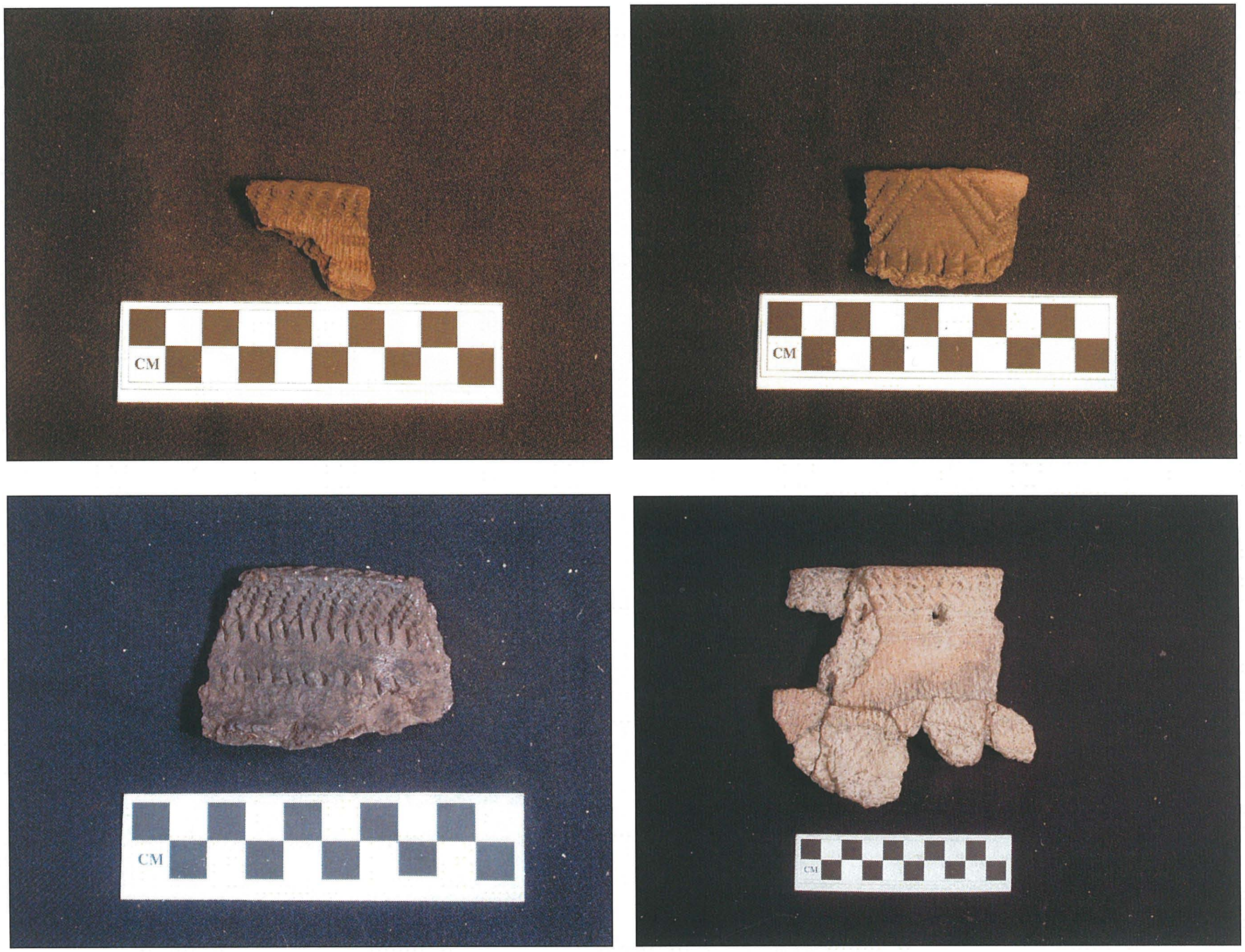


Figure 43. Blackduck sherds from the Long Sault (DdKm-1), Meek (DjKp-3), Rowdy Lake (EdKo-6), and Wapesi River (EdKb-1) sites.

Figure 44. Sandy Lake sherds from the Dowse (DkKr-2) and Two Point Sand Bar (EcKc-4) sites.